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Determination of Capture and Destruction Efficiencies of Selected Volatile Organic Compound Control Devices in the State of Illinois

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by

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Prepared for:

U. S. Environmental Protection Agency
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ABSTRACT

This report provides technical support for the development of the Illinois State Implementation Plan for surface coating industries, and more specifically, paper and can coating. A source testing program was conducted at three paper coating and two can coating facilities in Illinois to determine the efficiency of capture and destruction of volatile organic compounds (VOC) using either carbon adsorption or afterburner systems. At the paper coaters, the VOC collection efficiencies were 91-94%, but at the can coating plants, collection efficiency was undetermined. On the paper coating lines, two carbon adsorbers showed 79 and 98% control efficiency and a thermal afterburner was performing at 95% efficiency. The three afterburners at the can coating plants were controlling only 26 to 73% of the VOC's because operating temperatures were relatively low. EPA Method 25 was used to determine the VOC concentration in the vapor streams.

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SECTION 1

SUMMARY

The State of Illinois, in Rule 205(n)(2)(A) of its State Implementation Plan (SIP), has proposed that where operators of surface coating lines elect to use add-on controls for volatile organic compounds (VOC) emissions, the overall efficiency of capture and destruction should be at least 75%. This level of control differs from the presumptive norm of 81% overall efficiency for add-on control equipment supported in the U.S. Environmental Protection Agency's Control Technology Guidelines (CTG's). Therefore, the State committed to complete a study of surface coating categories currently using add-on controls in Illinois to determine what levels of capture and control efficiencies are technically feasible for a) the current systems, and b) for those facilities that would require retrofitting.

In this study, a source testing program was conducted at three paper coaters and two can coating facilities to evaluate the current performance of their existing add-on control systems. Information was collected relative to possible means of improving the performance of the control system. Testing was conducted on three thermal afterburners, one catalytic afterburner, and on two carbon adsorbers. To prevent disclosure of proprietary information, the facilities tested were assigned code letters. A summary of the findings at the five test sites is presented in Tables 1-1 and 1-2 for the paper and can coaters, respectively.

Paper Coating Facilities

At two of the paper coaters, C and E, the collection efficiencies were 94-98% and 94%, respectively, but it was undetermined at D. The thermal oxidizer at C was operated at 95-96% destruction efficiency giving a 91-93% overall control. The carbon adsorber at E was determined to have a 98%

TABLE 1-1. SUMMARY OF VOC COLLECTION AND RECOVERY/DESTRUCTION EFFICIENCIES OF SURFACE COATING OPERATIONS AT PAPER COATERS

Plant Code	A [1]	B [2]	C	D	E [2]	F	G [2]	H [1]	I [1]
Collection Efficiency, % (E_1)	-	-	94-98	Unk	94 [7]	-	-	-	-
Afterburner (Destruction) or Carbon Adsorption (Recovery) Efficiency, % (E_2)	96-97 [3]	- [4]	95-96 [3]	79 [4,6]	98 [4,6]	85 [3]	- [4]	97-99 [3]	98-99 [3]
Overall Control Efficiency, % (E_3) ($E_3 = E_1 \times E_2$)	-	90 [5]	91-93	$\leq$79	92 [5]	-	93-96 [5]	-	-
Source of Data	Ref 5	Ref 6	Field Test 10/80	Field Test 10/80	Field Test 10/80	Ref 7	Ref 8	Ref 9	Ref 10
Source of Data									

Remarks:

[1] Gas analyses by flame ionization detector.

[2] Solvent balance.

[3] Thermal oxidizer.

[4] Carbon adsorber.

[5] Based on makeup solvent requirements and data supplied by the plant.

[6] Based on VOC measurements of adsorber offgas.

[7] Calculated: $E_1 = E_3 \div E_2$

TABLE 1-2. SUMMARY OF VOC COLLECTION AND DESTRUCTION EFFICIENCIES OF SURFACE COATING OPERATIONS AT CAN MANUFACTURERS

Plant Code	L	M		P	Q	R	S
Type of Operation	Sheet Coating	Sheet Coating		Inside Spray	Sheet Coating	Sheet Coating	Inside Spray
Type of Afterburner	Thermal	Line 1 Thermal	Line 2 Catalytic	Thermal	-	Thermal	Thermal
Collection Efficiency, % (E_1)[2]	221[2,4]	174[4]	90[3]	77	74-79	73	12
Afterburner Destruction Efficiency, % (E_2)	73	26[5]	49[5]	-	-	89	-
Overall Control Efficiency[1] % (E_3) ($E_3 = E_1 \times E_2$)	-	-	44	-	-	65	-
Source of Data Source of Data	Field Test 10/80	Field Test 10/80	Field Test 10/80	Ref 2	Ref 3	Ref 4	Ref 4

Remarks:

[1] Assuming all captured emissions are routed to afterburner.

[2] 37% of the "captured" vapors are subsequently vented directly to the atmosphere from the oven's cooling zones rather than being sent to the afterburner.

[3] 12% of the "captured" vapors are subsequently vented directly to the atmosphere from the oven's cooling zones rather than being sent to the afterburner.

[4] Unexplainable high value based on plant sampling and production data supplied by plant.

[5] Low efficiency attributed to low operating temperature of afterburner.

recovery and a 92% overall efficiency. The carbon adsorption system at Plant D was performing at only 76% efficiency. No explanation for the low value was available but the normal design performance is in excess of 90%. Results of control system performance at six other facilities in the country are included in Table 1 to supplement the limited testing of this program. At three plants, A, H, and I, the thermal oxidizers (afterburners) performed at 96-99% efficiency, but at Plant F, which operated its oxidizer at a lower temperature, only 85% was observed. The overall control efficiencies of 90 and 93+% at B and G, respectively, reflects high collection and carbon adsorption performance.

From these observations, it may be concluded that a collection efficiency of 90+% at any given paper coating facility is reasonable if:

- the coating applicator zone is close-coupled or hooded to the drying oven,
- the coating room is sealed from the outside and maintained under a slight negative pressure so that essentially all the VOC emissions from the coater are drawn into the oven, and
- all exhausts from the oven are ducted to an add-on control device, i.e., a carbon adsorption bed or an afterburner.

Carbon bed adsorbers can be designed to provide at least 90% recovery of VOC emissions introduced into the control system. Continuous operation at close to design performance is possible if the system is properly monitored and maintained. Similarly, thermal afterburners have been demonstrated to destroy at least 90% of the VOC emissions entering the system, especially if operated at a temperature in excess of 1400°F and with an adequate residence time, e.g., 0.3 seconds.

Therefore, at paper coating facilities, overall control of VOC emissions at 81% or higher efficiency appears technically feasible on the basis of achieving 90% capture of the emissions and 90% control of the captured emissions using a conventional add-on control system.

Can Coating Facilities

At the two can coating facilities tested in this program, Plants L and M, sheet base coating was the only operation controlled as shown in Table 1-2. On one coating line, a VOC collection efficiency of 90% was observed but at two other lines, the data imply efficiencies in excess of 100% and must be discarded. Because the control systems are not operated in the winter months, it was not possible to repeat the testing. To supplement these observations, results were included from four facilities in other states. The VOC collection efficiencies of the sheet coating operations at Q and R sites were 73 to 79%. For sites P and S, where an inside spray operation was performed, the collection efficiencies were 77 and 12%, respectively. Earlier studies have shown that the distribution of emissions between the coater-flashoff area and the drying oven varies with the type of can coating operation being performed. When base coating sheets, only 10% of the total emissions may occur at the coater-flashoff areas, but with inside spray operations, up to 80% of the solvent flashes off. The balance of the emissions come from the oven. Therefore, the low value reported for Plant S is understandable, and reflects the range in performance that may be observed at different coating facilities.

Once the coating material enters the drying oven, the potential VOC emissions are contained. However, the oven itself is a source of emissions if it is not maintained at a negative pressure relative to its surroundings. Also, the cooling zones of the oven may vent VOC's unless the zones are exhausted to an add-on control device. At Plants L and M, the cooling zones of the drying ovens exhausted directly to the atmosphere and contained 37% and 12%, respectively, of the VOC vapors leaving the ovens.

To obtain 90% or better collection efficiency, one alternative is to completely enclose the existing sheet coating lines as well as all other coating operations. This is especially true for plants which operate several coating operations in one building. However, the technical feasibility of maintaining a proper air balance between the room and the oven zones is not readily determined. An alternate method of enhancing collection efficiency is through the use of more hooding and floor sweeps. In any case, the oven cooling zones should be designed and operated to minimize exhausting VOC's to the atmosphere.

The afterburners tested at the can coating plants in this program were performing at relatively low levels, i.e., 26-89%. In some cases, the systems were designed for low temperatures primarily for odor control and hence their performance may be improved by increasing the operating temperature.

In summary, the level of overall control of emissions from any given can coating operation is heavily dependent on the technical feasibility of enhancing the capture efficiency of VOC's from the coating line. Can coating lines are frequently in large, unsealed buildings and may be laid out in a more open fashion than paper coating lines.

Measurement Procedures

The total gaseous nonmethane (TGNMO) procedure, EPA Method 25, was selected for the gas-phase analyses in lieu of using a flame ionization detection (FID) technique to determine the carbon concentration of streams to and from add-on controls. The sampling procedure is relatively simple and the laboratory analytical procedures have been demonstrated. When analyzing mixtures of solvents and/or products of partial combustion, it may be more cost-effective than using gas chromatographic-mass spectrometric techniques. A need was identified to develop a modified Method 25 procedure to analyze for the concentration of carbon in the liquid coating materials to more readily determine the capture efficiency of coating lines.

SECTION 2

INTRODUCTION

In the proposed Illinois State Implementation Plan (SIP), Rule 205(n)(2)(a) contains an alternative compliance option for owners and operators of surface coating lines whereby the sources are exempt from the requirement to use high solid coating materials if emissions of volatile organic compounds (VOC) are controlled by an afterburner system. The overall efficiency of capture and destruction of the nonmethane volatile organic materials is proposed to be at least 75%. This differs from the 90% capture of emissions or the 81% overall control efficiency (capture plus control) which represents the presumptive norm for add-on control equipment as technically supported in the Control Technology Guidelines (CTGs).[1,1] Because the State did not submit technical support for the lower level of control, the State committed to complete a study to evaluate the VOC categories currently using add-on control technology (i.e., afterburner systems) in Illinois and to determine the capture and destruction efficiencies for these systems along with associated plant engineering data. This report describes the details and observations of a field sampling study performed during October, 1980 as a part of this committment.

The U.S. EPA in its final determination, 45FR11482, stated that, although 90% capture systems are Reasonably Available Control Technology (RACT) as a general matter, because the CTGs do not address unique circumstances, the State is free to determine RACT on an individual source basis.

2.1 BACKGROUND

The surface coating industry consists of eight major categories of sources:

- Cans
- Paper
- Fabric products
- Metal coils
- Magnet wire
- Metal furniture
- Large appliances
- Automobile and light-duty trucks

Although the coating materials, process equipment, operating techniques and control technology used by one source may also be used in part by another source in a different category, there are considerable variations or options used by the industry as a whole as well as unique circumstances for many facilities.

Based on earlier reviews, the EPA Regional Office V requested that the emphasis be placed primarily on the can and paper coaters. In two categories, metal coils and magnet wire, the VOC emissions are currently effectively controlled by afterburners and/or use of waterborne formulations. Control technology used by the can and paper coaters may possibly be transferred to the two major fabric coating facilities in Illinois. In the other three categories, automobile/truck, metal furniture, and large appliance coating, it is anticipated that implementation of high solids and/or waterborne formulations, as well as improved transfer efficiencies, will occur rather than the continued use of solvent-based formulations and add-on controls.

Although the study did not address the overall compliance plans for individual facilities, it should be noted that the Illinois SIP, in Rule 205(n)(4), provides for the use of internal offsets. This allows a plant to apply the "bubble concept" and use a combination of control techniques. Thus, for those specific operations in which it is difficult to capture a high percentage of the VOC emissions in a concentration that can be incinerated or adsorbed, a company may elect to use the bubble approach in their compliance plans.

2.2 TEST SITE SELECTION

The general criteria for selecting can and paper coating facilities for field testing included:

- located in the State of Illinois, preferably near Chicago,
- currently using add-on controls, i.e., afterburner or carbon adsorption system,
- operation representative of other facilities in the state, and
- employs control technology that can be applied to other surface coating facilities.

Although facilities with afterburners were of more concern because they are mentioned specifically in Rule 205(n)(2)(A), carbon adsorption systems were also investigated because of their applicability and ease of sampling.

Other desired, but not necessarily required criteria, were those specific to the technical aspects such as:

- the coating formulation uses a single solvent or a mix that can be analyzed with reasonable accuracy by a flame ionization detector (FID)
- solvent consumption can be readily measured

- sample points exist or can be easily installed on the control device inlet and outlet
- solvent-laden air flow in and out of the control device can be readily measured
- each control device services only one coating line

The major can and paper coating facilities in the Chicago area were first reviewed on the basis of information obtained from the State of Illinois and then subsequently by telephone calls. Finally, the most likely candidate sites were visited prior to testing to determine the feasibility of obtaining adequate performance data.

To preclude disclosure of proprietary information, all of the sources have been assigned code letters and will be referred to by these letters in this report.

2.2.1 Can Coating

Of the 21 major can manufacturing facilities in Illinois, only 10 are currently using afterburners (A/B). Six plants have thermal units, two have catalytic, and two have both types. These controls are generally on the sheet coating ovens, but at two plants, they are on the lithographic press lines.

The total number of emission sources at can coating facilities in the state is approximately 434. Of these, only 73 are coating ovens and 51 are press ovens. The distribution of emission sources by types of operations and number of sources controlled follows:

	Total Units	Number Controlled	Type of Control
Coating Ovens	73	36	24 Thermal A/B 12 Catalytic A/B
Press Ovens	51	10	8 Thermal A/B 2 Catalytic A/B
All Other Operations*	310	4	3 UV Resin 1 Heat Sensitive Coating

*Includes inside and outside stripe, side seam, inside coating, end coating, end sealing compound, and body spray.

The type of controls used by ten can manufacturing plants is presented in Table 2-1. All but one of the sources are in the Chicago area.

Two sources, L and M, were selected for field sampling on the basis of their meeting most of the major criteria. In no case does any source use a single solvent or simple mixture of compounds that would allow ready analysis of the emissions using a flame ionization detector (FID). For that reason, it was decided to use the recently developed EPA Method 25 to determine total gaseous nonmethane organic carbon concentration as described in Section 4.

2.2.2 Paper Coaters

Of the 31 major paper coating facilities in Illinois, only six are using add-on controls, three of which have afterburners and the other three use carbon adsorption. (Two plants use waterborne coatings and one uses ultraviolet curing.) The type of control used in these plants is given in Table 2-2.

Any source using a carbon adsorption system can normally provide reliable data on capture efficiency since the makeup solvent rate to the system, less any liquid withdrawals to controlled waste solvent disposal and VOC left in the absorber off-gas, equals the fugitive VOCs not captured. Source D and E using carbon adsorption and Source C using afterburners were selected as candidates for field testing. As with the can coaters, none of the paper coaters uses a "simple" solvent mixture in its formulations.

TABLE 2-1. CAN MANUFACTURERS WITH AFTERBURNERS IN ILLINOIS

Facility Code	Operation Controlled		Type of A/B Control	
L	Coating Oven	(3)	Thermal	(3)
M	Coating Oven	(8)	Thermal Catalytic	(3) (5)
N	Coating Oven	(2)	Thermal	(2)
T	Litho Oven	(6)	Thermal Catalytic	(2) (1)
U	Coating Oven Lithographic Oven	(2) (3)	Thermal Thermal	(2) (3)
V	Coating Oven	(4)	Thermal	(4)
W	Coating Oven	(6)	Catalytic	(2)
X	Coating Oven	(9)	Catalytic	(1)*
Y	Coating Oven Coating Oven	(4) (8)	Catalytic Thermal	(4) (8)
Z	Coating Oven	(6)	Catalytic	(2)

( ) = Number of ovens or control devices
* = One control on 3 ovens

TABLE 2-2. PAPER COATING FACILITIES WITH ADD-ON CONTROLS IN ILLINOIS

Facility Code	Controls		Control Device Efficiency* %
	Number	Type	
A	1	Afterburner	97
C	7	Afterburner	98
D	6	Carbon Adsorber	97
E	3	Carbon Adsorber	90
J	7	Carbon Adsorber	85
K	3	Afterburner	97

*Reported by plant management.

SECTION 3

SURFACE COATING PLANT CHARACTERIZATION

The five surface coating plants selected for field testing to determine VOC emission capture efficiency and afterburner or carbon adsorption efficiency, while typical of other such plants in Illinois, do have some unique features that are cited in the following paragraphs. In certain cases, they affect the overall performance value and, therefore, these factors should be considered in determining what is optimum performance for a normal installation.

The VOC emissions from a paper or can coating line come either from the application-flashoff area or from the drying ovens. For can coating operations, there may also be emissions associated with the cooling zone. (Depending on the coating operation being performed, the application-flashoff emissions may range from 0 to 100%, and 0 to 100% may come from the ovens.) Although VOC vapors released in the drying ovens are normally contained at close to 100% efficiency (for safety and health reasons), they may either be exhausted to the atmosphere or be processed by add-on control systems, i.e., carbon adsorption or incineration. Where a mixture of solvents is used, or where the organic material cannot be recycled, incineration is generally the preferred control.

The design parameters for incinerators are well established and systems are readily designed to perform with 90-95%, or higher, destruction of VOC.[1] The operating efficiency of afterburners, both thermal and catalytic, can be determined by analyzing the inlet and outlet streams. The primary design parameters are oxidizer temperature and residence time.

The efficiency of capture of emissions from the coating equipment and flashoff area is difficult to measure unless the entire coating line is enclosed and operated under negative pressure. One method to determine capture efficiency is by a material balance wherein the fugitive loss is based on the difference between two large values, i.e., the mass of solvent input to the coater, less the mass of solvent ducted to the add-on control device.

3.1 CAN COATING

A general characterization of the selected plants, "L" and "M", is presented in Table 3-1 and includes the process operations performed, the types of vapor collection and afterburners used. Table 3-2 indicates the operating parameters of the coating lines as reported during the pretest site visits. The types of solvents and coating materials used are listed in Appendix C, but no specific formulations are indicated since they are proprietary and also are varied quite frequently. The typical operating parameters of the afterburners are shown in Table 3-3. In Tables 3-1, 3-2, and 3-3, data are also included for facilities not tested in this study but for which performance data are available from earlier investigations by others.

3.2 PAPER COATING

Three paper coating plants, "C", "D", and "E", were tested during this project. The general characteristics of these plants are presented in Table 3-4 and the coating line operating parameters in Table 3-5. The afterburner operating parameters are shown in Table 3-3, and the carbon bed parameters in Table 3-6. As was the case with can coating, the specific formulations used in the coating are proprietary so only the components are indicated in Appendix C.

TABLE 3-1. CHARACTERIZATION OF CAN COATING FACILITIES

Plant Code	Products	Processes	No. of Lines	SLA Collection System*	Afterburners No.	Afterburners Type	Remarks
L	Sheet Coating (Enamel Plate)	Sheet Base Coating (Exterior and Interior)	2	Hoods over Coaters	2	Thermal	(1)
M	Two-Piece and Three-Piece Cans	Sheet Base Coating	8	None	5 3	Catalytic Thermal	(1)
		Printing/Lacquer Coating	9	-	9	Thermal	-
P	Two-Piece Cans	Interior Spray Coating	4	Hood	-	Thermal	(2)
Q	Three-Piece Cans	Sheet Base Coating	1	None	None	-	One Cooling Zone (3)
R	Three-Piece Cans	Sheet Coating	6	-	-	Thermal	(4)
S	Three-Piece Cans	Interior Spray	9	-	-	Thermal	(4)

*In addition to oven exhaust. SLA = Solven-laden air.

Remarks: (1) Tested 10/80.
(2) Tested 10/79. See Ref. 2.
(3) Tested 10/79. See Ref. 3.
(4) CARB Study, Ref. 4.

TABLE 3-2. OPERATING PARAMETERS OF CAN COATING FACILITIES

Plant Code	Line Number	Line Speed (sheets/min) Range	Line Speed (sheets/min) Average	Type of Coating	Coating Weight (mg/in^2)(wet) Range	Coating Weight (mg/in^2)(wet) Average	Run Length** (hrs)
L	1	85-105	105	Enamels	3.5-10	-	72-120
M	1	90-110	100	Vinyls or Epoxies	1-12	11.0 Vinyl 4.5 Epoxy	24
	2	-	-	Print Ink	Varies	3.0	>24
P	4	650 cans/ min	-	Inside Spray	-	-	-
Q	1	100 max	-	Base Coat	-	-	-
R*	1	-	75	-	-	4.2	-
S*	-	380 cans/ min	-	-	-	0.28 g/can	-

*See Reference 4.
**Supplied by plant management.

TABLE 3-3. OPERATING PARAMETERS AND PERFORMANCE OF AFTERBURNERS AT SURFACE COATING FACILITIES

Plant Code	Unit No.	Type of Afterburner	Heat exchange		Auxiliary fuel		SLA Flow		Outlet Flow		VOC (lb/hr)		Afterburner Eff., %	Data source
			Primary	Secondary	Type	10^6 Btu/hr	MSCFM	°F	MSCFM	°F	In	Out		
Can Coaters														
L	1	Thermal	Yes	No	NG	13	-	350-400	25-35	1300-1500	-	-	-	Plant Mgr.
	2	Thermal	Yes	Yes	NG	-	8	350-450	25-35	1300-1500	0.348	0.0963	72	Test 10/80
M	1	Thermal	No	No	NG	-	4.4	148	3.2	551	0.349	0.260	26[4]	Plant Mgr.
	2	Catalytic	No	No	NG	-	7.0	228	6.4	548	0.566	0.291	49[4]	Plant Mgr.
Paper Coaters														
C[2]	1	Thermal	Yes	No[3]	NG	-	17.9	342	12.5	1250(870)	7.89	0.43	95	Test 10/80
	1	Thermal	Yes	No[3]	NG	-	17.9	342	12.5	1250(870)	7.54	0.27	96	Test 10/80

[1]Measured as carbon.
[2]Plant C was tested during two separate periods.
[3]Afterburner exhaust directly reused in drying oven.
NG = Natural gas
SLA= Solvent-laden air
[4]Low efficiency attributed to low operating temperature.

TABLE 3-4. CHARACTERIZATION OF PAPER COATING FACILITIES

Code	Web Material	No. of Lines	Continuity of Operations	Condition of System	SLA* Collector System	Control Device
C	Paper	4	24 hr/day 6 day/wk	Very Good	Oven exhaust only. Applicator close connection to oven	Thermal afterburners
D	PVC film Mylar film	2	24 hr/day 5 day/wk	New	Complete coating room control	Carbon adsorber
E	Paper	2	24 hr/day 5 day/wk	Very Good	Complete coating room control	Carbon adsorber

*SLA=Solven-laden air

TABLE 3-5. OPERATING PARAMETERS OF PAPER COATING FACILITIES

Plant Code	Process	Line No.	Line Speed ft/min	Type of Coating	SLA SCFM	Control Device °F
C	Paper Coating	1	(Proprietary Information)		18,000	1250[1]
D	Web Coating	1	45	Pressure-Sensitive Adhesive & Release	30,000	70[2]
		2	55.5	Pressure-Sensitive Adhesive, Laminate Adhesive & Release		
E	Paper Coating	1	60	Nitrocellulose	10,400	70[2]
		2	60	Nitrocellulose		

[1]Thermal afterburner
[2]Carbon Adsorber

TABLE 3-6. OPERATING PARAMETERS OF THE CARBON ADSORBER

Plant Code	Unit No.	Number of Beds	Pounds of Carbon Per Bed	Superficial Velocity (fpm)	Pounds of Steam Per Pound of Recovered Solvent	SLA Flow	
						MSCFM	°F
D	1	3	7,000	<100	NA	30,000	72
E	1	3	6,000	90	5-6	10,400	90

NA - Not Available

SECTION 4

TEST PROCEDURES

Test procedures were selected to permit the determination of the efficiency of any VOC collection system used to recover a mixture of known or unknown solvents from a coating line and to measure the efficiency of the add-on controls. The procedures were developed either by EPA or the American Society for Testing and Materials (ASTM) or are slight modifications thereof.

Because the surface coaters studied in this program do not use a single solvent but rather use a mixture of solvents, the analysis of gas streams by conventional gas chromatography or flame ionization detector is very difficult or nearly impossible. Therefore, it was necessary to use a carbon balance approach to determine the efficiencies. EPA Method 25 was selected to provide the solvent concentration in the gas streams since the result can be expressed in moles of carbon per volume of gas and is independent of the molecular configuration of the solvents present. Using this method obviates the problems associated with trying to identify the actual solvent species or their derivatives resulting from partial oxidation in ovens or afterburners. The need to calibrate any FID for each VOC species in the concentration range that exists in the plant gas stream is also avoided.

Capture efficiency was determined by comparing the mass of carbon passing through the collection system per unit time (using Method 25) with the mass rate of carbon charged to the coating applicator via solvents. The mass rate was determined from the measured coating rate, analyses of the density and volatile content, and the carbon content of the solvent fraction. In one case, the mass rate was determined by the plant personnel to maintain the proprietary formulation.

The efficiency of the control device was determined by comparing the amount of carbon recovered (in carbon adsorbers) or destroyed (in afterburners) to the mass of carbon entering the control device. For afterburners, the efficiency is determined through gas-phase analysis for carbon content. For carbon adsorbers, gas-phase analysis and solvent balances were used.

The procedures for sampling and analyzing the liquid and gas streams are discussed in the following paragraphs.

4.1 LIQUID SAMPLE PROCEDURES

Grab samples were taken from each coating line for the different solvent-based coatings applied during the test runs. The samples were analyzed in the Radian laboratory for volatile content using ASTM Procedure D2369-80 and for density using ASTM D1475-60. Portions of the coatings were distilled using ASTM Procedure D3272-76 to provide a solvent that could be analyzed for carbon content using a modification of EPA Method 25. This latter analysis was performed by Truesdail Laboratories, Inc., Los Angeles, California. From these four analyses and procedures, it was possible to calculate the mass of carbon per mass of coating charged to the applicator. Details of these test methods are provided in Appendix A.

The results of the individual laboratory analyses for density, volatile content, and mass of carbon per mass solvent are compared with the estimates provided by the plant personnel in Table 4-1. Not all of the plants supplied complete data on their coatings, but the table identifies those plants where data exists. In general, the laboratory analyses of the coating samples are supported by the estimates provided by the plant.

The coating application rate was estimated from plant process data. The most reasonable approach was to take the coating weight data determined routinely by the operators and multiply that by the process feed rate. The

TABLE 4-1. COATING CHARACTERISTICS: TEST VALUES VS PLANT DATA

Plant	Type of Coating	Density (gm/cm^3)		Volatile Content, Wt%		Mass C /Mass Solvent (lb/lb)	
		Test Value	Plant Estimate	Test Value	Plant Estimate	Test Value	Plant Estimate
E	Ink	0.8894	NA	71.1	68	0.748	0.748
E	Ink	0.8858	NA	66.6	68	0.748	0.748
L	Enamel	1.0355	1.013 ± 0.05	22.7	18-25	0.848	NA
L	Enamel	1.3744	NA	34.1	NA	0.725	0.735
D	Adhesives	-	-	-	-	.87-.90	0.88

NA = Not Available

coating weights for can coating operations are generally expressed in milligrams per one square inch or four square inches, while the paper coaters generally express their weights in pounds per 3000 square feet (one ream). The feed rate for can coating is usually in sheets per minute while paper coating, which is a continuous web operation, is in feet per minute.

Other methods for calculating the coating application rate were considered but rejected. Measuring weight or volumetric changes in the coating feed tanks was not feasible primarily due to the inaccuracy of tank measurements taken over a relatively short (one hour) test period, and the lack of accurate volumetric data on the applicator tank. Also, in some cases, minor modifications are made to the formulations during the run by adding solvents or thinners. It is very difficult to maintain an accurate record of these additions.

4.2 GAS-PHASE MEASUREMENTS

The gas-phase measurements consisted of volumetric flow, molecular weight, moisture, and VOC concentration. These measurements were performed as described in EPA Methods 1 through 4 and 25. (See Appendix A) The gas analyses were performed by Pollution Control Science, Inc., (PCS) of Miamisburg, Ohio, and by Truesdail Laboratories, Inc., of Los Angeles, California, using Method 25. The velocity, molecular weight, and moisture analyses were performed by the on-site Radian test team.

An S-type pitot tube and a magnehelix were used to obtain the pressure readings for the velocity measurements. The pitot and magnehelix gauges were calibrated for the tests and their calibration curves are given in Appendix B. At one plant, an Alnor® velometer had to be used to measure the duct gas flow rate. Information on the Alnor and its calibration is also provided in Appendix B.

With Method 25, the bulk of the solvent vapors in the gas stream is condensed in a cold trap chilled with dry ice. Any noncondensible gases including noncondensible organic vapors pass through the trap and are collected in an evacuated cylinder of known volume. Both the trap and evacuated cylinder are then analyzed off site for total gaseous nonmethane organics. These values permit the calculation of the total carbon concentration in the gas stream expressed in parts of carbon per million of gas on a volume basis. A detailed description of Method 25 is given in Appendix A.

To supplement the Method 25 tests, the solvent concentrations were measured by a Century® Organic Vapor Analyzer (OVA) and by charcoal tube grab samples. The OVA was used to monitor the system performance. Usually, the sample probe was located at the control device entrance and the monitor showed the variations in solvent concentration due to process upsets, start-ups, and shutdowns.

The charcoal tube samples were taken as a backup to the Method 25 analysis. A measured amount of solvent-laden air was passed through the tube over about a 30-minute period and the activated charcoal adsorbed the VOC emissions. The tubes can be analyzed in an off-site laboratory to determine the solvent concentration. Due to limited resources and the fact that the gas analyses by Method 25 appeared to be satisfactory, the charcoal tubes were not analyzed.

An indication of the accuracy of the Method 25 tests can be seen from the results of the tests at Plant C. Plant C personnel provided the rate of solvent applied with the coating in terms of carbon mass per minute for each of three sample periods. For these sample periods, a different solvent application rate was used. The average VOC concentrations measured during these periods using Method 25 correlated well with the VOC application rates calculated by the plant and based on their proprietary formulation (Figure 4-1).

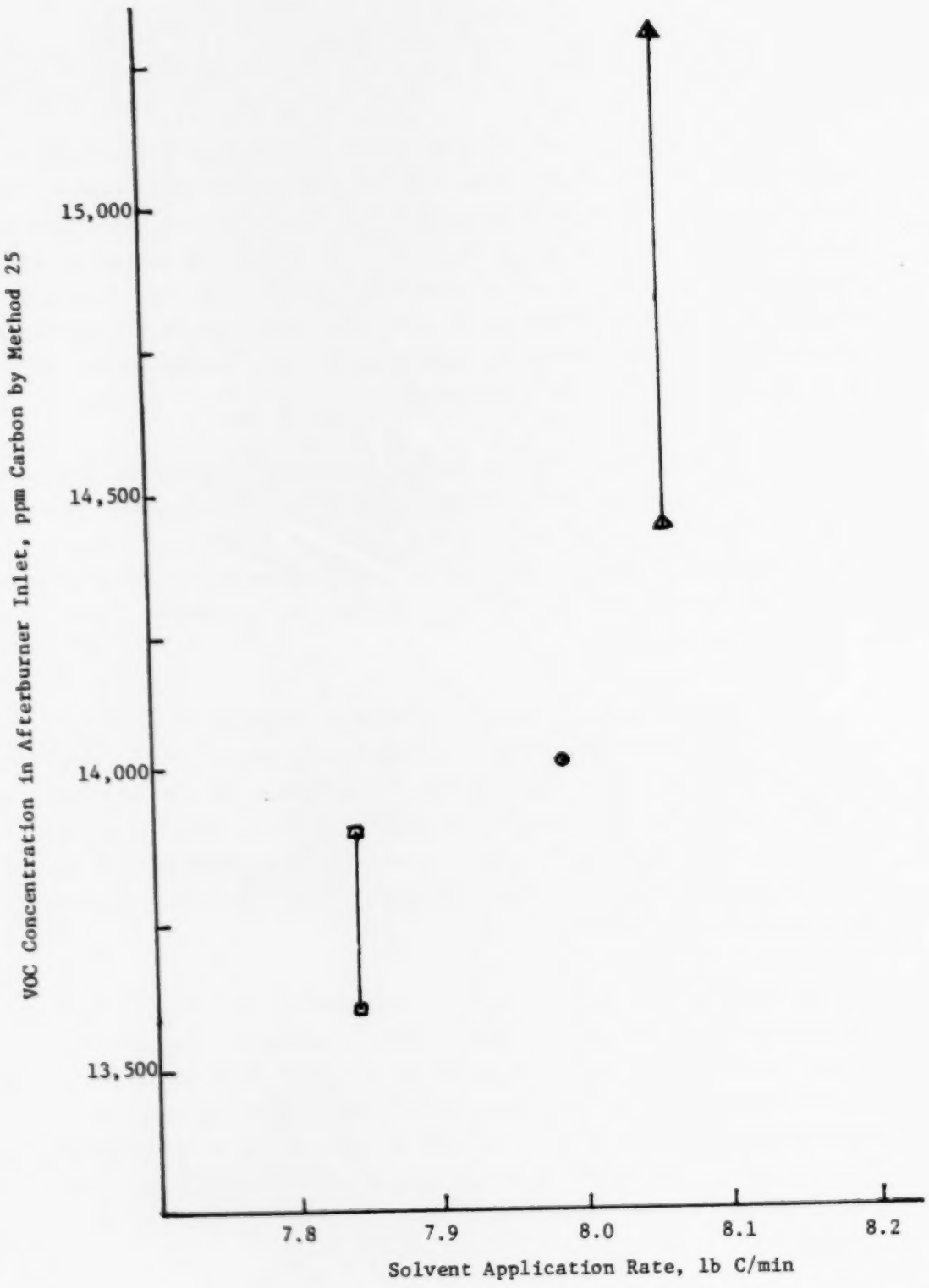

Figure 4-1. Response of afterburner inlet VOC concentration with variations in coating rate at Plant C.

There were not enough analyses performed to determine the precision of the data when using EPA Method 25. However, repeatability over a concentration range from 200 to 15,000 ppm is indicated in Table 4-2 and in Figure 4-2. With two exceptions, the range of analyses is 275 ppm or less and is relatively independent of the concentration.

TABLE 4-2. RESULTS OF REPLICATE GAS SAMPLES USING EPA METHOD 25

Plant ID	Samples ID	Carbon Concentration, ppm			Percent Deviation From the Mean*	Range of Analyses ppm
		Test 1	Test 2	Mean		
C	Afterburner Inlet	15,290	14,431	14,860.5	± 2.9%	859
C	Afterburner Inlet	13,895	13,620	13,757.5	± 1.0%	275
L	Afterburner Inlet	1,696	1,527	1,611.5	± 5.2%	169
L	Afterburner Outlet	613	454	533.5	±14.9%	159
L	Cooling Zone A	259	180	219.5	±18.0%	79
L	Cooling Zone B	519	263	391	±32.7%	256
M (Line 1)	Afterburner Inlet	2,320	3,146	2,733	±15.1%	826
M (Line 2)	Afterburner Inlet	2,783	2,688	2,735.5	± 1.7%	95

*Percent deviation from the mean DFM calculated as follows:

$$DFM = \frac{(Test\ 1 - Test\ 2)/2}{(Test\ 1 + Test\ 2)/2} \times 100$$

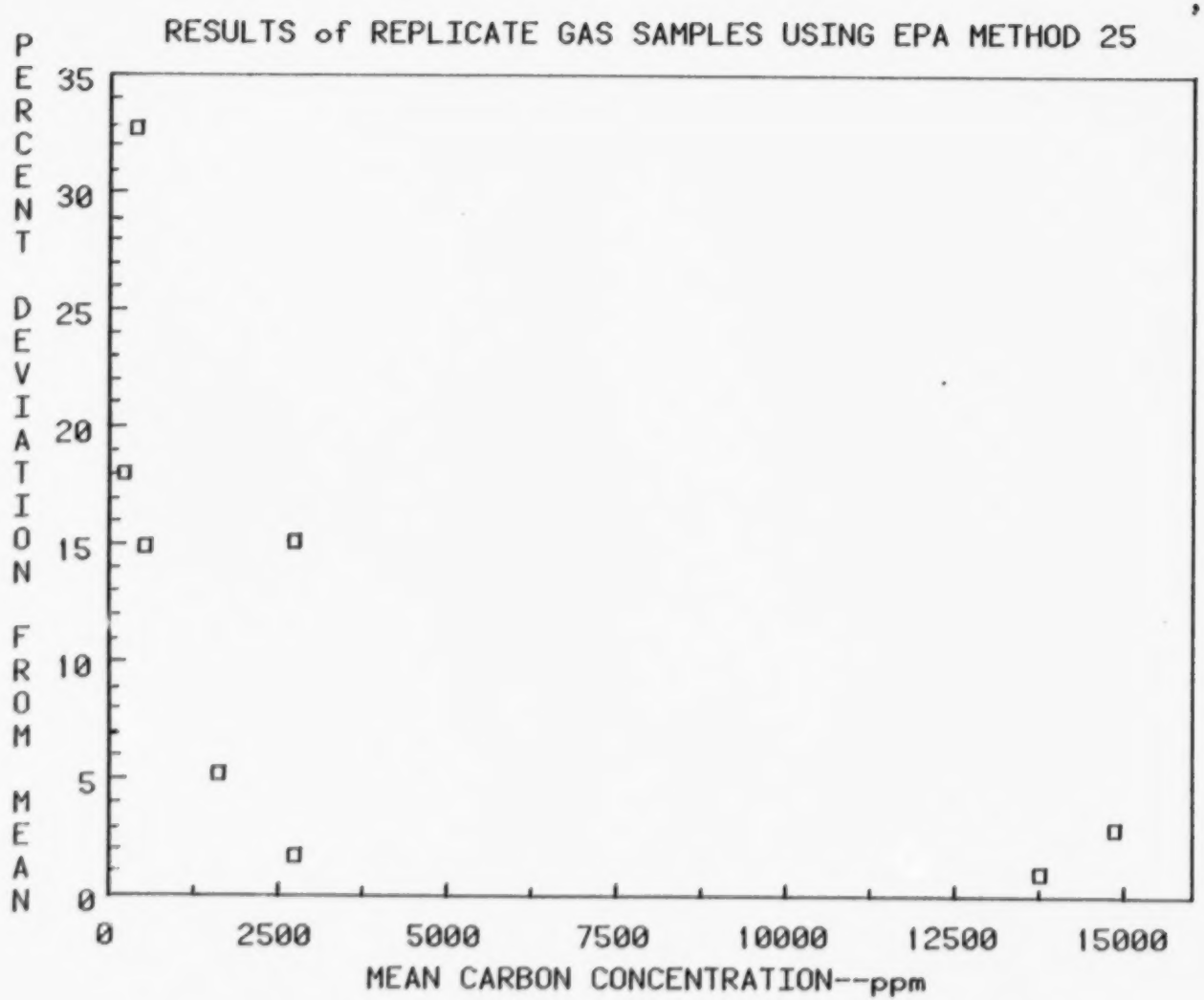

Figure 4-2. Deviation from mean of carbon analyses of replicate gas samples using EPA Method 25.

SECTION 5

DISCUSSION OF RESULTS

Field tests were conducted at three paper coating and two can coating facilities in Illinois to measure the actual efficiency of VOC capture or collection systems and the efficiency of add-on control devices to recover or destroy the VOC emissions. In addition, engineering data were collected at the plant sites to assist in the estimation of reasonable performance for any plant with a well-designed and operated VOC collection and abatement device.

The raw data collected in the field are assembled in Appendix D. These data are used to calculate the application rates and gas flow in the ducts leading to and from the control devices. The results of the liquid and gas-phase analyses are also provided in Appendix D. Sample calculations are included in Appendix E.

This section presents and discusses the results of the material balance calculations for collection, control device, and overall efficiencies at the sites tested.

5.1 PAPER COATER, PLANT C

The paper coating facility tested at Site C consists of a single coating line controlled by a thermal oxidizer-type afterburner. A schematic of the facility is shown in Figure 5-1. Due to the confidentiality agreement with Plant C, the test contractor was not allowed in the coater room. Also, the contractor could not take grab samples of the coatings or any engineering data on the coating line. However, Plant C did provide the solvent application rate expressed as total carbon (Table 5-1) and some coating line and afterburner operating parameters (Table 5-2).

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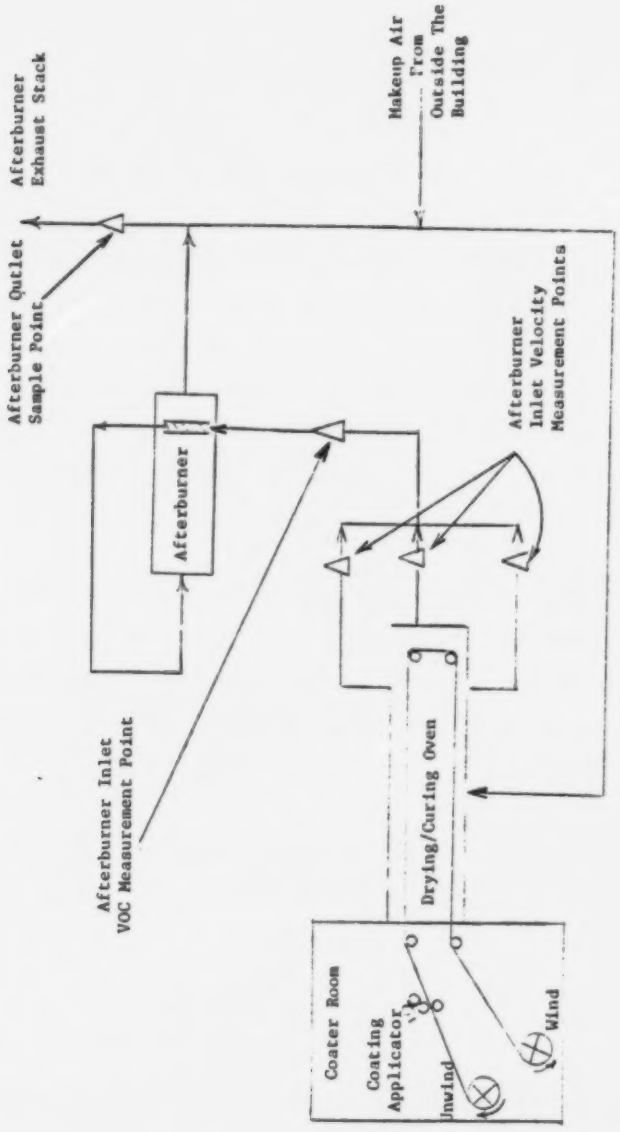


Figure 5-1. Schematic of Plant C paper coating facility.

TABLE 5-1. SOLVENT USAGE REPORTED BY PLANT C DURING TEST PERIODS

Test Date: October 29, 1980

Time	Carbon atoms/hr	lb C_1/Minute
1200 - 1335	10.9×10^{27}	7.988
1335 - 1600	11.0×10^{27}	8.061
1600 - 1810	10.7×10^{27}	7.841
1810 - 2040	10.9×10^{27}	7.988

Gas sampling was performed during the time intervals of 1435 - 1535, 1655 - 1755, and 1917 - 2017.

TABLE 5-2. PLANT C OPERATING PARAMETERS

Coating Line Operating Parameters		
Web substrate	-	continuous paper roll
Line speed	-	(confidential)
Line width	-	(confidential)
Coating material	-	adhesive and release
Coating weight	-	(confidential)
Weight percent solvent	-	(confidential)
Solvent composition	-	(confidential)
Afterburner Operating Parameters		
Type of Afterburner	-	Thermal oxidizer
Solvent-laden air to afterburner	-	18,000 scfm
Afterburner temperature	-	1,250 °F
Residence time		0.3 seconds

Gas-phase analyses were performed at the afterburner inlet and outlet. The results of these measurements are shown in Table 5-3. There were no accessible sample locations directly before the afterburner unit. Therefore, the inlet flow rate had to be estimated from the sum of the combined outlet flow rates of the three hot air streams leaving the drying/curing oven. Due to physical limitations in the location of the sample ports in the oven outlet ducts, the S-type pitot could not be used to measure the velocity in the ducts. Instead, an Alnor velometer had to be used. (A discussion of the Alnor velometer is given in Appendix A.)

The expected VOC capture efficiency for this facility is 100 percent based on the assumption that all VOC-laden gas streams (or SLA) are eventually pulled through the drying/curing oven and then through the afterburner. The VOC capture efficiency was measured for two distinct one-hour time periods. From 1435 to 1535, the solvent capture efficiency was 97.9% of the solvent applied at the coater. For the period 1920 to 2020, the capture efficiency was 94.4%.

The VOC destruction across the afterburner was determined to be about 95 to 96%. The temperature in the incinerator was 1250°F and the residence time was estimated at 0.3 seconds. This good performance of the afterburner may be attributed in part to the high VOC concentration in the inlet stream.

The overall VOC control based on the capture and destruction efficiencies are 92.5 and 91.0% for two one-hour tests, respectively.

5.2 PAPER COATER, PLANT D

Plant D is a typical example of a facility with two coating lines which each coat more than one coating and which are controlled by a single carbon adsorption system. In one of the two coating lines, a vinyl plastic film is first given one anchor coat and then a final coat of pressure-sensitive adhesive. The final product is electrical tape. The second line

TABLE 5-3. GAS-PHASE TEST RESULTS FOR PLANT C

Sample Location	Test No.	Gas Flowrate (scfm)	Gas Temperature (°F)	VOC Concentration (vppm as C_1, dry)	VOC Flowrate (lb C_1/min)
Afterburner Inlet	1	17,920	342	14,861[a]	7.888[b]
	2			14,088	7.538[b]
Afterburner Outlet	1	12,500	1250(870)[c]	1,151	0.433
	2			721[d]	0.271

[a]Average of two samples - 15,290 and 14,431.

[b]Does not include carbon in the recycled gas to the oven.

[c]Outlet of primary exchanger.

[d]Average of two samples - 597 and 844.

first coats an adhesive which laminates nylon strands to a Mylar® film and then the film is coated with one release coat and one coat of pressure-sensitive adhesive. The final product is strapping tape. A schematic of the coating lines is shown in Figure 5-2. Plant operating parameters are given in Table 5-4 and characteristics of the coatings are in Table 5-5.

The Plant D facility was designed to ensure maximum capture of solvent VOC emissions. The coater room is maintained at a slight negative pressure with respect to the ambient outside pressure. All of the drying/curing ovens are either ducted directly to the main header to the carbon adsorption system or they are ducted to another oven which is subsequently ducted to the main header. There are also several hoods, primarily over the coating applicators, which are ducted to the main header to the carbon adsorber system. The overall effect should be essentially 100 percent VOC capture.

The carbon adsorption system is a typical three-bed system which was installed in 1974. A schematic of the system is shown in Figure 5-3. It operates with two beds adsorbing and one bed regenerating. The beds are switched on-and-off by VOC monitors in the exhaust stacks. When the VOC breakthrough concentration is reached, i.e., about 40 ppm toluene, the bed is shut off and steamed.

The only gas-phase analyses performed at Plant D were measurements of the gas flow rate and VOC concentrations in the carbon adsorber exhaust stacks. Each bed had an exhaust stack. The gas flow rates through each bed were nearly identical (about 15,000 scfm); therefore, all the gas measurements were averaged for all three stacks. The results are shown in Table 5-6.

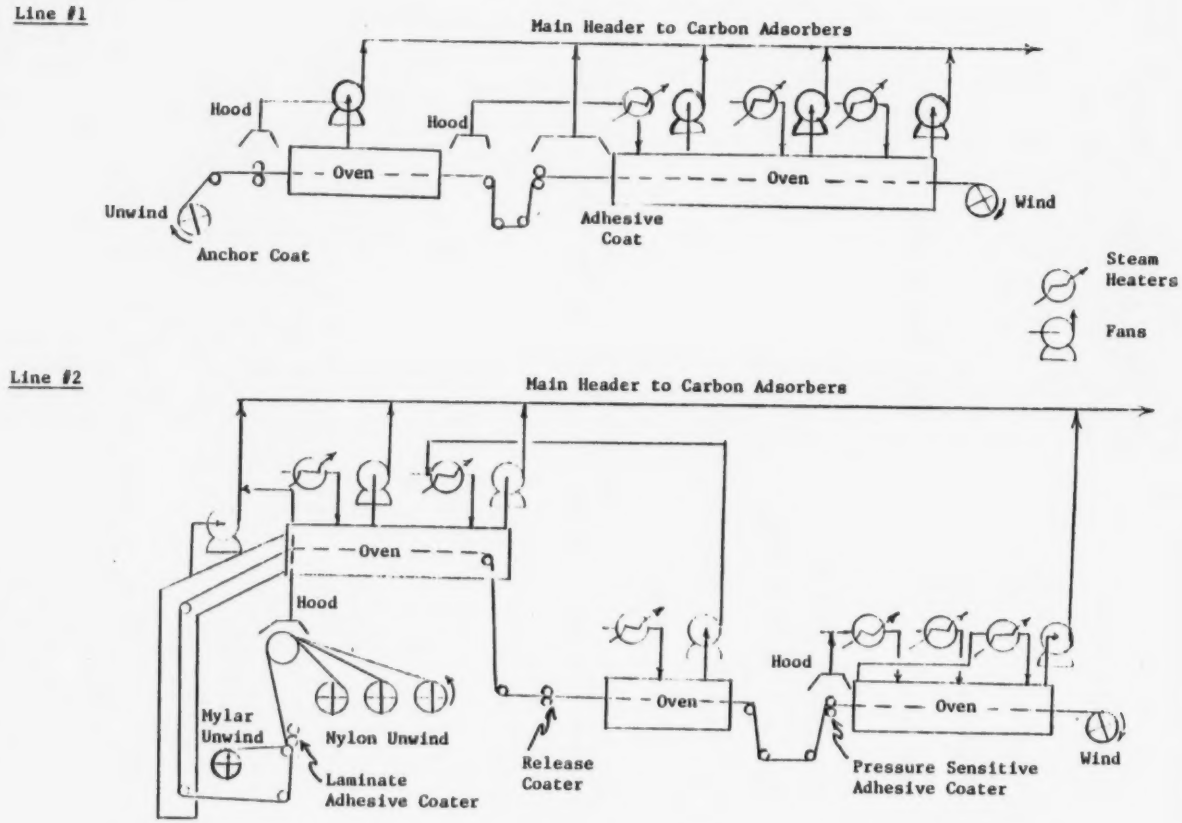


Figure 5-2. Schematic of Plant D coating facilities.

TABLE 5-4. PLANT D OPERATING PARAMETERS

Coating Line Operating Parameters

	Line #1	Line #2
Web substrate	PVC	Mylar
Line speed (fpm)	45	55.5
Line width (inches)	36	59
Coating Characteristics	(see Table 5-5)	

Carbon Adsorber Operating Parameters

Number of beds - 3 (2 on/1 off)

Weight of carbon per bed (lbs) - 7,000

Superficial velocity (fpm) - <100

Steam Consumption (lb steam/lb recovered solvent) - Not measured

TABLE 5-5. PLANT D COATINGS CHARACTERISTICS

Line #	Type of Coating	Coating weight (gallons/1000 yd^2)	Coating density (gm/cm^3)	Volatile Content, wt %	Pound of carbon per pound of solvent	Solvent application rate (lb C_1/min)
1	Anchor Coat	7	0.8666	91.0	0.8986	0.621
1	Pressure Sensitive Adhesive	45	0.9231	57.1	0.8873	2.634
					Total Line #1	3.256
2	Laminate Adhesive	20	0.889	28.1	0.8858	1.133
2	Release	3	0.8605	99.3	0.8685	0.564
2	Pressure Sensitive Adhesive	40	0.8761	27.6	0.8703	2.130
					Total Line #2	3.826
					Total Lines #1 & #2	7.0816

TABLE 5-6. GAS PHASE TEST RESULTS FOR PLANT D

Sample Location	Gas Flowrate (scfm) (wet)	Gas Temperature (°F)	VOC Concentration (ppm as C, dry)	VOC Flowrate (lb C/min)
Adsorber Outlet	14,940[a]	72	1,692[c]	1.54[b]

[a]Average gas flowrate per exhaust stack.

[b]Total for the two adsorber exhaust stacks on line.

[c]Based on average of 2018, 2029, 2203, 1214, 919 and 1767.

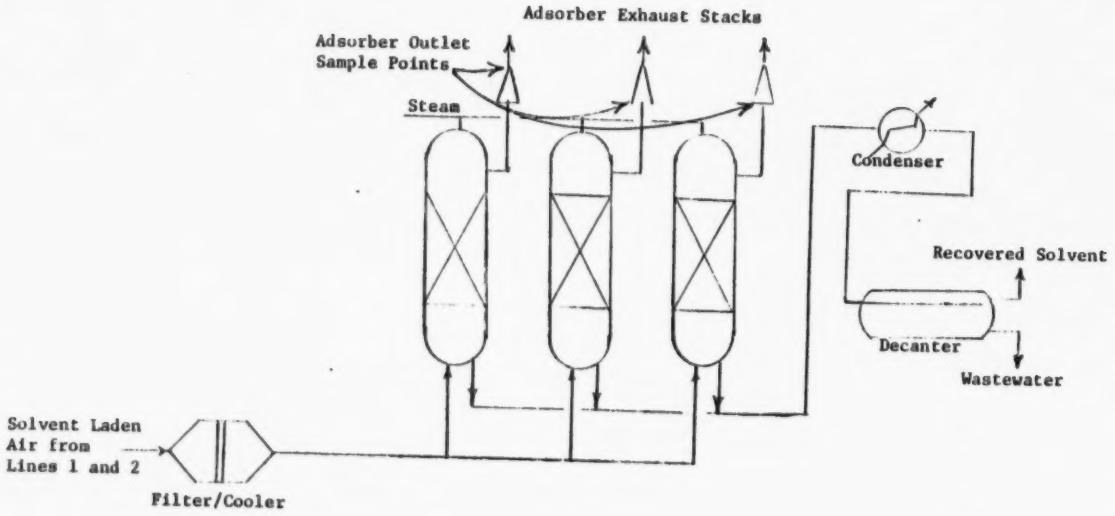


Figure 5-3. Schematic of Plant D carbon adsorber system.

Plant D could not estimate their overall percent recovery of the solvents used in the coatings as originally expected. Therefore, the control device performance was calculated assuming 100% capture of the 7.1 lbs/min of carbon fed to the two coating lines. The 1.5 lbs/min of carbon leaving in the carbon adsorber exhaust streams indicates an efficiency of only 79%. There is no obvious explanation for this low value but it is supported by current above-average solvent purchases by the plant. The analysis of six exhaust samples averaged 1692 ppm C or equivalent to 242 ppm toluene. This is significantly higher than the 104 ppm toluene level set on the hydrocarbon breakthrough detector. If the detector were out of calibration or otherwise not receiving a representative sample, it would permit operation beyond the desired range before switching the beds to the steaming cycle. Recent routine testing of a carbon sample from the bed by the equipment manufacturer did not indicate any deterioration of the carbon. The plant is investigating the possibility of a partial by-pass of gas flow around the carbon beds.

5.3 PAPER COATER, PLANT E

Plant E is an example of a well-designed system for VOC capture. Plant E consists of two paper coating lines which are ducted to a single carbon adsorption system. The coating lines are relatively small and produce a nitrocellulose-coated paper which is used as stencil paper for mimeograph machines. A schematic of Plant E is shown in Figure 5-4. The normal plant operating parameters are shown in Table 5-7.

As with Plant D, Plant E operates with their coating room at a slight negative pressure with respect to the outside ambient pressure. The overall effect is for all of the oven makeup air to come from the coater room and be pulled through the drying oven. This should effect 100 percent VOC capture of the solvent used in the coatings.

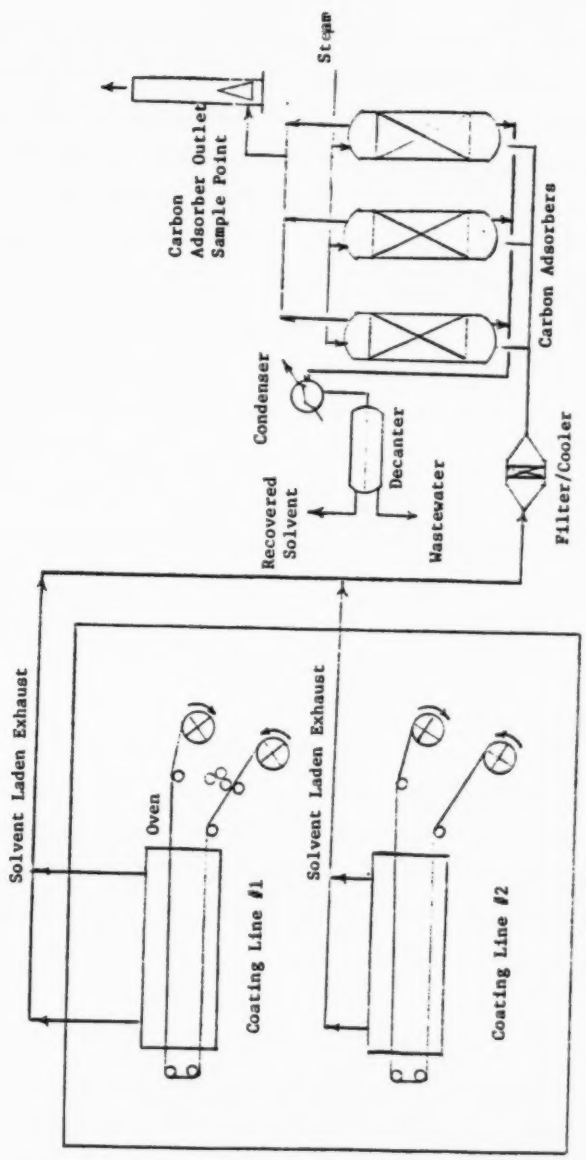


Figure 5-4. Schematic of Plant E paper coating facility.

TABLE 5-7. PLANT E OPERATING PARAMETERS

Coating Line Operating Parameters

	Line #1	Line #2
Web substrate	paper	paper
Line speed (fpm)	60	60
Line width (inches)	34	34
Coating solids material	nitrocellulose	nitrocellulose
Coating weight (lb/3000 ft^2)	30	32
Coating density (gm/cm^3)	0.8894	0.8858
Solvent content (wt %)	71.1	66.6
Pound carbon per pound solvent	0.748	0.748
Solvent application rate (lb C_1/min)	0.9045	0.9035

Carbon Adsorber Operating Parameters

Number of beds - 3 (2 on/1 off)

Weight of carbon per bed (lbs) - 6000

Superficial velocity (fpm) - 90

Steam consumption (lb steam/lb recovered solvent) - 5-6

The adsorber system has three beds with a single exhaust stack. The beds operate with two adsorbing and one regenerating and their switching is based on VOC breakthrough. During the test periods, a typical bed would adsorb for one hour and steam for one-half hour. Gas-phase analyses were only performed at the carbon bed exhausts.

The results of the gas-phase analyses are shown in Table 5-8. The VOC concentration represents the average of six one-hour tests using EPA Method 25 over a five-and-one-half-hour period. Both coating facilities operated for nearly the entire period. No sampling problems were encountered during the test period.

The plant engineering staff routinely monitors the performance of the solvent recovery, distillation, storage, and feed systems. They also determine the overall solvent recovery from flow measurements. For the 12 months ending November 30, 1980, the average recovery was 92.14 percent. Although this value varies slightly from month to month, due to the effect of temperature on the efficiency of the carbon adsorber, it has been noted that for the months of April, May, September, and October, the recovery approximates the annual average.

Based on the calculated carbon mass rate to the coaters of 1.808 lb/min, the adsorber carbon exhaust rate of 0.032, and a 92 percent overall recovery, the carbon rate to the adsorber was calculated at 1.696 lb/min. This indicates a 98 percent recovery across the carbon adsorber and a 93.8 percent capture efficiency. The 6% not captured may be accounted for as residual solvent in the product leaving the ovens, solvent handling losses, and fugitive losses from the coating line.

The carbon beds and the VOC breakthrough monitors are therefore very effective, even though the carbon has been in service for six years. The plant routinely measures the length of time the beds are on stream before breakthrough to follow the gradual loss in adsorption capacity caused by the buildup of heavy organic or other coating components that are not readily desorbed in the steam cycle.

TABLE 5-8. GAS-PHASE TEST RESULTS FOR PLANT E

Sample Location	Gas Flowrate (scfm)	Gas Temperature (°F)	VOC Concentration (ppm C, dry)	VOC Flowrate (lb C/min)
Adsorber Outlet	10,350	90	104*	0.0328

*Average of six test runs: 159, 120, 58, 153, 90, and 42 ppm carbon.

5.4 CAN COATER, PLANT L

This can coating facility applies a single enamel coat to sheets of tin plate which are used to make three-piece cans. After being coated with the solvent-based enamel, the tin plate sheets are dried in a wicket-type oven. As shown in Figure 5-5, the exhaust from the drying oven is ducted to an afterburner. At the end of the oven are two cooling zones where outside room air is drawn in over the hot sheets to cool them before stack-out. Both of the cooling zones are exhausted directly to the atmosphere. Additional information on the coating facility and afterburner is given in Table 5-9.

Gas-phase samples were taken at the afterburner inlet, afterburner outlet, and both cooling zones. A velocity traverse could not be done at the afterburner inlet because there was no suitable site. However, the afterburner did not use any additional air for combusting the solvents in the oven exhaust gases. Therefore, the afterburner exhaust rate was used to estimate the afterburner inlet flow rate. The sample ports at the afterburner exhaust and cooling zones were satisfactory for both velocity and VOC measurements. The results of the gas-phase analyses are shown in Table 5-10.

When the amount of solvent ducted to the afterburner inlet plus that in the cooling zone gas streams is compared with the amount of solvent applied at the coating applicator, the VOC capture is calculated at 221 percent. Obviously, this number is in error. The error was initially thought to be in the data on the applied coating. However, all of these numbers were verified by Plant L as correct. No explanation for the poor material balance has yet been determined. From the gas-phase analyses, the afterburner VOC destruction efficiency is calculated at 73 percent.

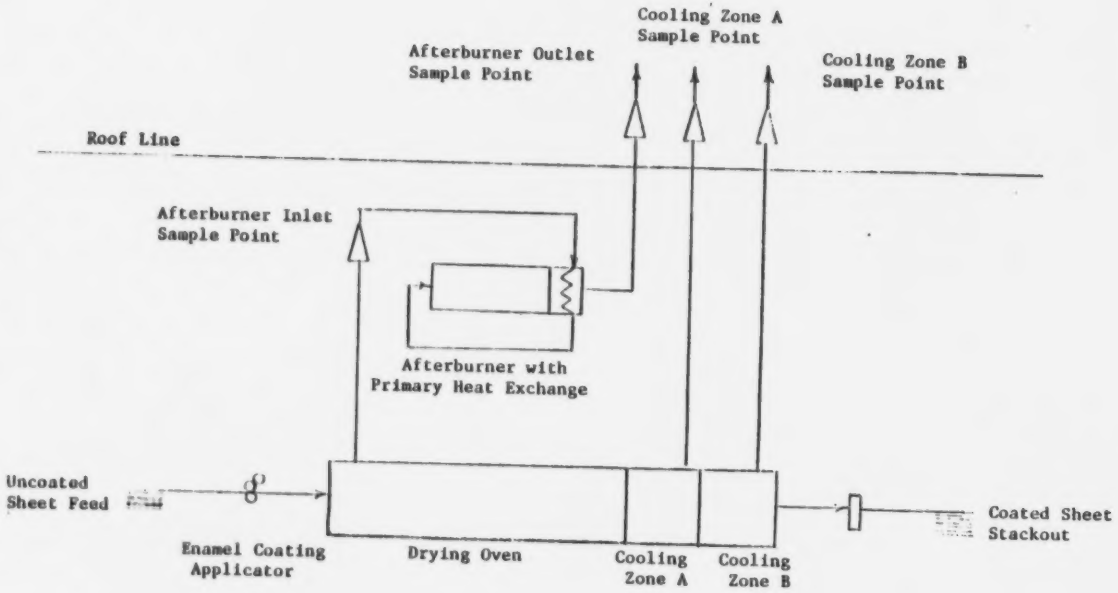


Figure 5-5. Schematic of Plant L can coating facility.

TABLE 5-9. PLANT L OPERATING PARAMETERS

Coating Line Operating Parameters		
Sheet material	-	Tin plate
Line speed (sheets/min)	-	105
Sheet dimensions	-	33.125" x 33.369"
Coating material	-	enamel (1.0355 gm/cm^3)
Coating weight (mg/in^2, wet)	-	5
Solvent content, Wt %	-	22.7
Solvent composition (lb C/lb solvent)	-	0.8483
Solvent application rate (lb C/min)	-	0.246
Afterburner Operating Parameters		
Type of afterburner	-	thermal oxidizer
Solvent laden air to afterburner (scfm)	-	7,750
Afterburner temperature (°F)	-	1200
Residence time (sec)	-	1.8*

*Estimated by plant engineer

TABLE 5-10. GAS-PHASE TEST RESULTS FOR PLANT L

Sample Location	Gas Flowrate (scfm)	Gas Temperature (°F)	VOC Concentration (ppm as C, dry)	VOC Flowrate (lb C/min)
Afterburner inlet	7,750*	2200	1447	0:343
Afterburner outlet	7,980	787	389	0.0922
Cooling zone A	13,330	155	220	0.0897
Cooling zone B	10,800	118	336	0.111

*Estimated from incinerator exhaust flowrate.

5.5 CAN COATER, PLANT M

Two separate and different coating lines were tested at Plant M. The lines are designated as Line #1 and Line #2 and are discussed in the following subsections.

5.5.1 Line #1

Coating Line #1 consisted of two litho printers and one lacquer coater (Figure 5-6). The litho printers are fed base-coated, enameled sheets and use non-solvent-type colored inks to print the designs or wording of the can label. The sheet may be run through the litho presses one or more times depending on the desired number of colors; however, on the final print, the label is sealed with a solvent-based lacquer coat. This lacquer coat will protect the finish and give the can a glossy appearance.

The solvent emissions from the drying oven were ducted to a thermal afterburner. This afterburner operated at relatively low temperatures (500 to 600°F) and had no primary heat exchange. At the end of the oven was a single cooling zone which was ducted directly to the atmosphere. This unit was designed for smoke and odor control rather than VOC emission reduction.

During the testing, a lacquer coat was being applied. Table 5-11 gives the normal plant operating parameters during the test period.

Gas-phase analyses were performed at the afterburner inlet, afterburner outlet, and cooling zone exhaust. The results of these tests are given in Table 5-12. It was difficult to make good velocity measurements at any of the test sites. All of the test locations, except at the afterburner inlet, had duct runs which were shorter than those recommended in EPA Method 1. Therefore, rather than the normal 24 traverse points.

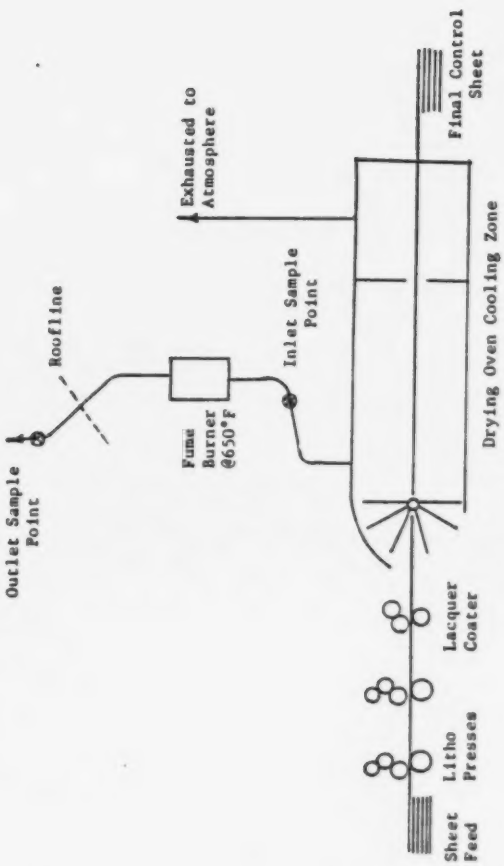


Figure 5-6. Coating line 1, Plant M.

TABLE 5-11. PLANT M OPERATING PARAMETERS - LINE #1

Coating Line Operating Parameters	
Sheet material	Tin plate
Line speed (sheets/min)	68
Sheet dimensions	33" x 34"
Coating material	Lacquer (0.935 gm/cm^3)
Coating weight (mg/4 in^2)	12
Solvent content, Wt %	58.0
Solvent composition (lb C/lb solvent)	0.7751
Solvent application rate (lb C/min)	0.227
Afterburner Operating Parameters	
Type of afterburner	Thermal
Solvent laden air to afterburner (scfm)	4,400
Afterburner temperature (°F)	550
Residence time (sec)	Unknown

TABLE 5-12. GAS-PHASE TEST RESULTS FOR PLANT M - LINE #1

Sample Location	Gas Flowrate (scfm)	Gas Temperature (°F)	VOC Concentration (ppm as C, dry)	VOC Flowrate (lb C/min)
Afterburner inlet	4,400	148	2,616	0.349
Afterburner outlet	3,170	551	2,678	0.260
Cooling zone	12,500	102	125	0.0478

the velocity was measured at 48 points. Even with this added data, the velocity measurements may be suspect. This is indicated in the data (see Table 5-12) which shows a much lower gas flow rate leaving the afterburner than the gas flow rate entering.

Another operational problem which hindered the gas-phase test work was the frequent stoppages of the coating line. During the test date, several mechanical problems were encountered with Line #1; therefore, the coater was turned on and off several times. The Century OVA was used to monitor fluctuations in VOC concentrations during the test run. The strip chart, Figure 5-7, shows typical fluctuations experienced at Line #1.

Due to the questionable velocity readings and the many facility startups and shutdowns, the material balances for the test period were very poor. The percent VOC capture was calculated at 174 percent and the VOC destruction across the afterburner was calculated as 26%. However, if the flow rates were assumed to be equal (since no additional air is added at the incinerator burner) and only the VOC concentrations are considered, i.e. 2616 vs. 2678 ppm, the VOC destruction is essentially zero. This may be true for an afterburner operating at such a low temperature (551°F).

5.5.2 Line #2

Coating Line #2 consists of a single coater and a single oven (Figure 5-8). The oven consists of six drying zones and one cooling zone. The gases in the drying zones flow countercurrent to the coated sheets. Finally, in Zone 1, the oven gases are exhausted to a catalytic oxidizer. Table 5-13 gives the operating parameters for Line #2 during the test date.

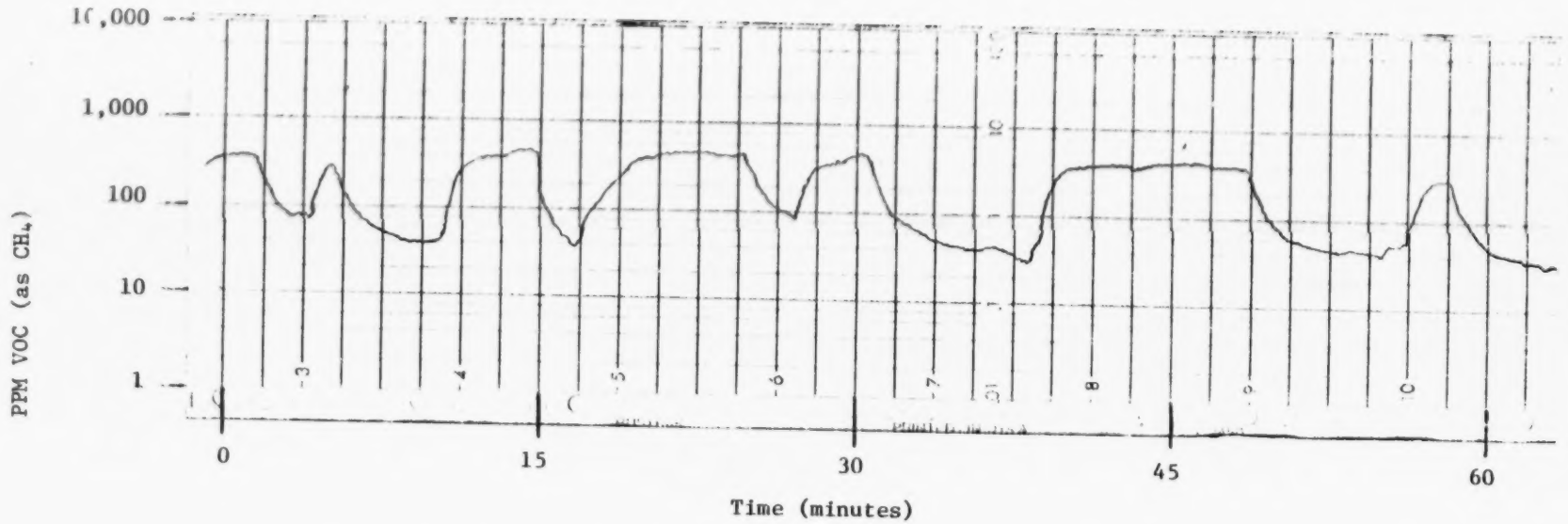


Figure 5-7 , Incinerator inlet VOC concentration (as CH_4) versus time, Plant M, Line #1

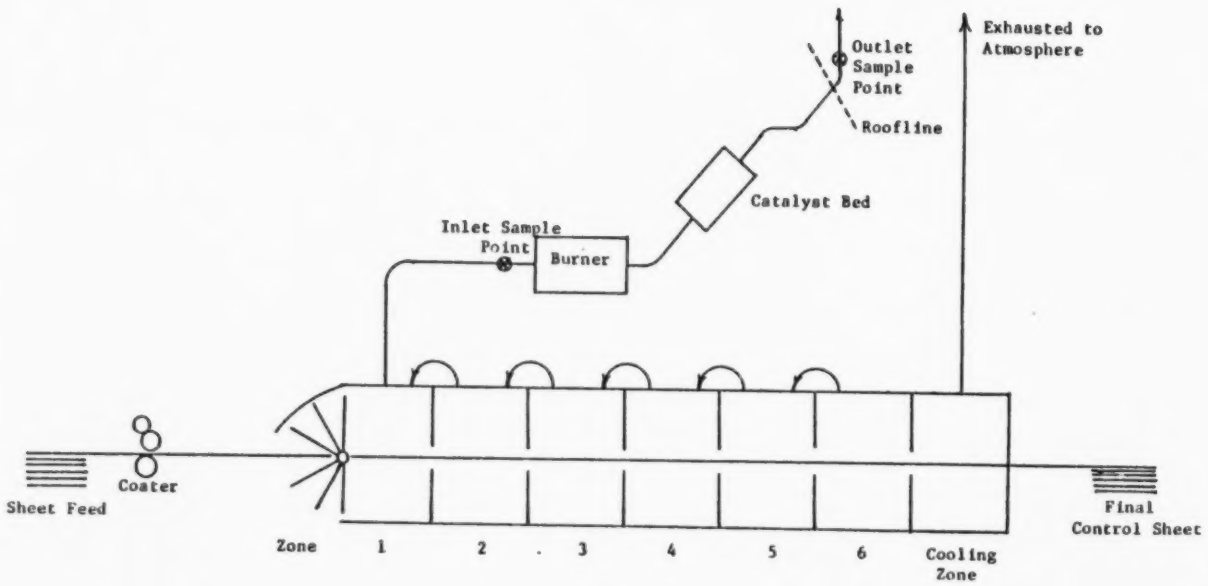


Figure 5-8. Coating line 2, Plant M.

TABLE 5-13. PLANT M OPERATING PARAMETERS - LINE #2

Coating Line Operating Parameters	
Sheet material	Tin plate
Line speed (sheets/min)	100
Sheet dimensions	33" x 34"
Coating material	Enamel (1.3744 gm/cm^3)
Coating weight (mg/4 in^2)	50
Weight percent solvent	34.1
Solvent composition (lb C_1/lb solvent)	0.7248
Solvent application rate (lb C_1/min)	0.764
Afterburner Operating Parameters	
Type of afterburner	Catalytic
Solvent laden air to afterburner (scfm)	6,930
Afterburner temperature (°F)	550
Residence time (sec)	Unknown

Gas-phase samples were taken at the afterburner inlet, afterburner exhaust, and cooling zone exhaust. The test results are shown in Table 5-14. As with Line #1, the velocity sample sites were not suited for accurate measurements; however, they were better than those on Line #1. Line #2 did experience process fluctuations but not as many as Line #1. The Century OVA hydrocarbon monitoring data for a typical operating hour for Line #2 is shown in Figure 5-9.

The material balance for Line #2 shows a potential 90% VOC capture efficiency. This includes 74% VOC captured in the oven which is routed to the afterburner plus 16% VOC which is currently exhausted from the cooling zone. The VOC reduction across the catalytic afterburner is calculated at 49%. This low value may be attributed to the relatively low operating temperature of 550°F rather than 600°F+ normally used for catalytic afterburners. This operating temperature was previously set to control odors rather than for VOC destruction according to the plant management. The potential overall efficiency is 44% (90 x 49%).

5.6 CAN COATERS, PLANTS OUTSIDE OF ILLINOIS

Because of limited time and resources, field tests were conducted at only two sites in Illinois. In order to provide more data, studies performed at seven other facilities outside Illinois by other companies were also considered. The results of these tests are presented in the next section, in Table 6-1, and are used to support the conclusions and recommendations. Five studies were performed using EPA Method 25, one with a flame ionization detector (FID) and one by means of a solvent material balance.

TABLE 5-14. GAS-PHASE TEST RESULTS FOR PLANT M - LINE #2

Sample Location	Gas Flowrate (scfm)	Gas Temperature (°F)	VOC Concentration (vppm as C_1, dry)	VOC Flowrate (lb C_1/min)
Afterburner inlet	6,930	228	2,696	0.566
Afterburner outlet	6,350	548	1,517	0.291
Cooling zone	27,310	94	144	0.119

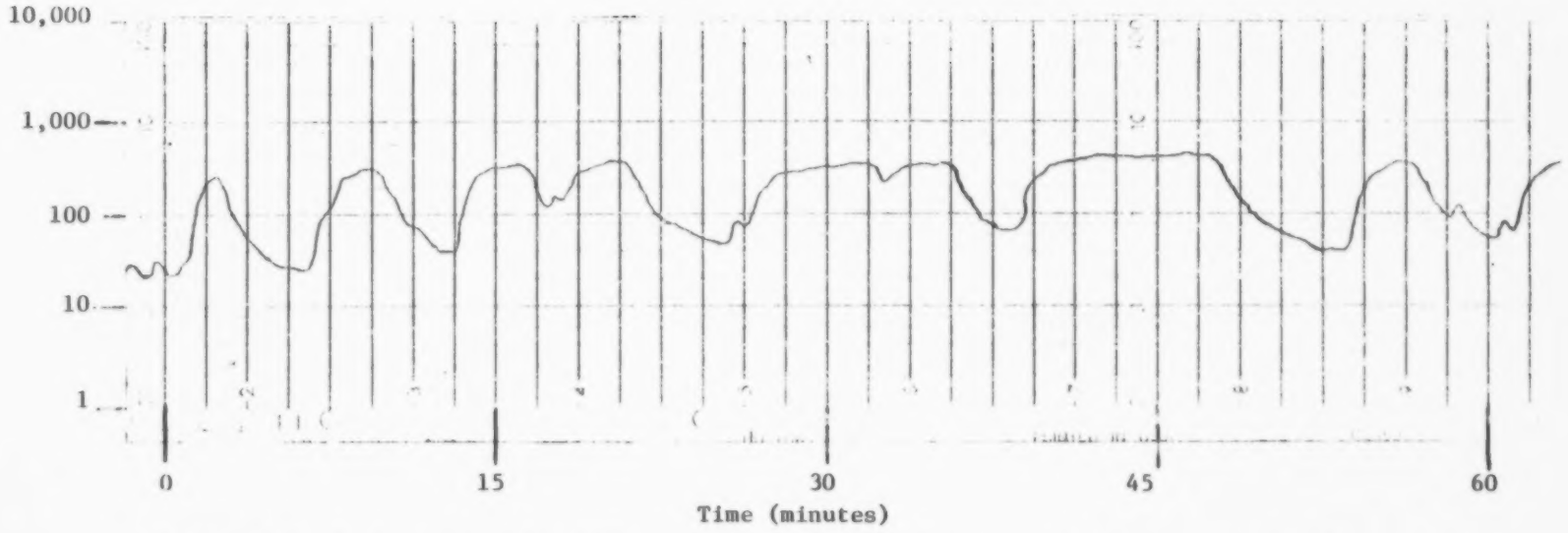


Figure 5-9, Incinerator inlet VOC concentration (as CH_4) versus time, Plant M, Line #2

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

Because of the small number of surface coating lines that were studied in this program, as well as the limited number of samples taken, it is difficult to draw conclusions from the performance of these specific lines and say that they are fully representative of any other facility or even the average of the others in Illinois. The best that can be expected is that the results may actually be representative of the sites tested.

However, from the observations made during the course of this program it is possible to make some judgments as to the performance that might be expected from surface coating facilities if reasonable collection and abatement equipment were provided and proper operational and maintenance procedures were followed.

The primary objective of the testing was to measure the VOC collection efficiency and the control device efficiency at each coating line. While this was accomplished, there were several notable exceptions that are discussed in the following paragraphs. The fact that the performance observed at some facilities was significantly below that proposed by either the EPA CTG guidelines or the Illinois SIP Rule 205(n)(2)(A), does not mean that better performance is not possible, and this will also be discussed.

A by-product of this study was the opportunity to evaluate the methodology for determining the performance of a surface coating facility. In particular, the recently developed EPA Method 25 to measure the total gas nonmethane organic carbon concentration in gaseous streams was

simple and cost effective. The field sampling procedures were straightforward and easily performed by those experienced in routine sampling of gaseous streams. The analyses were performed in off-site laboratories using established dry gas instrumental techniques such as gas chromatographic separation and oxidation and reduction. The potential problems of sample deterioration or diffusion through gas bags were precluded by Method 25. Alternate sampling and analytical methods would have been more costly, especially if speciation of the sample had been performed to achieve the necessary accuracy.

6.1 PAPER COATING OPERATIONS

From a review of the test data developed at three sites in this program, C, D, and E, plus recent data obtained by other investigators at sites A, B, F, G, H, and I, as presented in Table 6-1, it is possible to draw some conclusions about collection and control efficiencies.

Collection Efficiency

At sites C and E, the collection of VOC emissions was determined to be 100 and 94%, respectively. At site B, where the overall efficiency was determined to be 90%, if it is assumed that the carbon adsorber had a relatively high efficiency of 98%, then the capture must have been at least 92%. Unfortunately, the test results at D, A, and F do not permit a determination of the capture efficiency. However, if the coating rooms are operated under a slight negative pressure as was observed in Plants C, D, and E, and if the coating applicators are close coupled to the drying ovens, then the capture efficiency of paper coaters can normally be expected to be at least 90%.

TABLE 6-1. SUMMARY OF RECENT TEST DATA AT SURFACE COATING OPERATIONS

Plant ID	Type of VOC Control	VOC Test Method	VOC Capture and abatement efficiencies		
			% Capture[a]	% Control[b]	% Overall[c]
Paper Coating Facilities					
A*	TO	Flame ionization	NA	96-97	NA
B*	CA	Solvent balance	NA	NA	90
C	TO	Method 25	100	96	96
D	CA	Method 25	NA	76	NA
E	CA	Method 25	94	98	92
F*	TO	Method 25	NA	85	NA
G	CA	Material balance	NA	NA	93-96
H	TO	Flame ionization	NA	97-99	NA
I	TO	Flame ionization	NA	98-99	NA
Can Coating Facilities					
L[d]	TO	Method 25	221	73	NA
M (Line #1)[d]	TO	Method 25	174	26	NA
M (Line #2)[d]	CO	Method 25	90	49	64
P[e]*	TO	Method 25	77	NA	NA
Q[d]*	-	Method 25	74-79	NA	NA
R[d]*	TO	Method 25	73	89	65
S[e]*	TO	Method 25	12	NA	NA

TO = Thermal oxidizer, CO = catalytic oxidizer, CA= carbon adsorber, NA = not available.

[a]% capture is based on the sum of all solvent which leaves the facility in ducted gas streams. For can coating operations this includes the cooling zones and enclosed conveyers or elevators.

[b]% control is the VOC reduction across the control device.

[c]% overall is the maximum potential reduction of VOC, i.e., capture x control.

[d]Base coat applicator for a three piece can.

[e]Inside spray operations.

*Test programs conducted earlier by other investigators.

Control Device Efficiency

The five thermal oxidizers shown in Table 6-1 were determined to operate at 96, 96, 85, 97, and 98% efficiency at Plants A, C, F, H, and I. The design parameters of afterburners have been well developed and if properly operated at 1400°F with 0.3 seconds or more residence time, these units can routinely perform at 90-95% VOC destruction efficiency. The lower efficiency at Plant F might be attributed to an operating temperature (1200°F) below the design temperature.

The carbon adsorbers at Plant E were determined to be 98% efficient. At Plant B, if the capture efficiency was 99% or better, the carbon adsorber would have been operating at about 91% to have achieved the reported 90% overall control efficiency. This seems reasonable since carbon adsorbers have routinely been shown to be operated at 90-98% efficiency.

Carbon adsorbers lose capacity with age due to the buildup of heavy ends that are difficult to desorb during the steam regenration step. However, if a detector is used to signal the VOC breakthrough, it is possible to operate with a reasonably high efficiency, i.e., 90+%. When the on-stream cycle time becomes short, and the steam consumption becomes excessive, e.g., 8 pounds/pound of solvent recovered, then it is time to change out the carbon in the beds. At Plant D, the relatively low efficiency, may have been due either to a general loss in bed capacity, operating beyond the breakthrough point, insufficient steam during desorption, or the VOC detector being out of calibration. If operating problems are resolved, 90% or better recovery may be achieved.

Overall Control Efficiency

In at least four cases, the measured overall control was 90% or better. Based on an expected minimum capture efficiency of 90% as discussed above and a control device efficiency of at least 90%, the overall efficiency of a properly designed and operated paper coating line would be 81% or higher (90% x 90% = 81%).

Fugitive Emissions

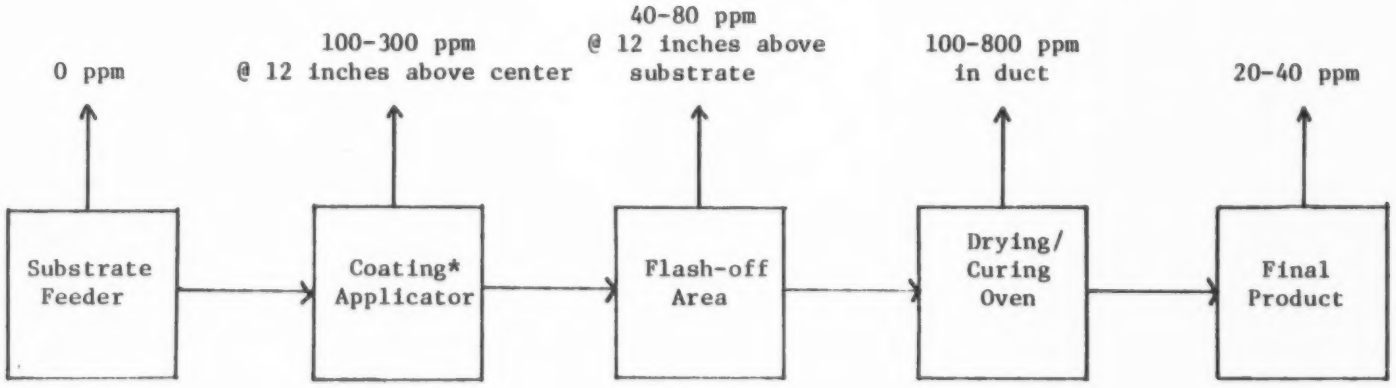
Instantaneous measurements of hydrocarbon concentration were taken in a survey of the production areas using a portable organic vapor analyzer (OVA). Figure 6-1 depicts the typical concentration of solvent vapor in the ambient air of a paper coating room. As would be expected, the concentration was highest directly above the coating applicator, and not as high in the flash-off area. This indicates that the solvent vapors tend to be carried along with the web and are drawn into the drying oven if it is operated with an adequate draft. It should be noted that even after drying, the final product continues to emit some small amount of solvent vapor. Earlier studies have indicated that generally 1 to 5% of the solvent used at the coater may still be present in the product leaving the oven.[15]

6.2 CAN COATING OPERATIONS

At the three tested can coating facilities, the only surface coating operation that used an add-on control device was sheet coating. This is apparently because it:

- is a major step in fabricating three-piece cans;
- is a continuous rather than intermittent operation;
- uses a high solvent rate at the applicator; and
- uses an oven to dry or bake the finish from which its exhaust can be easily ducted to a control device.

Other coating operations which do not generally have add-on controls, although they may have hoods exhausting directly to the atmosphere, are those which:



Notes: Readings were measured by a Century OVA meter, which was calibrated with methane.

*Readings directly over the applicator rolls and drip pan ranged from 800 to 1500 vppm depending on volatility of solvent.

Figure 6-1. Typical measurements of VOC concentration in vicinity of can and paper coating lines.

- are performed only intermittently, i.e. are not used for all product lines,
- use a low solvent application rate,
- use a waterborne coating or one requiring a UV cure, or
- do not require an oven.

Examples of these uncontrolled operations are:

- two- and three-piece can interior body spray,
- two-piece can exterior end (spray or roll coat),
- three-piece can side-seam spray, and
- end-sealing.

Collection Efficiency

The VOC capture or collection efficiency at a can coating line is more difficult to determine accurately than that of a paper coater for several reasons:

- the operation is subject to more frequent interruptions, especially if it is an old facility,
- the coating formulations are more complex,
- some coatings are relatively thin and hence the solvent rates are low, and
- oven cooling zones exhaust large volumes of air that may contain VOC vapors. This is possible if solvent vapors pass from the drying zone to the cooling zone because of an imbalance in pressure between the drying and cooling zones. Also, VOC's will enter the cooling zone if there is inadequate drying, resulting from too low an oven temperature, too short a residence time, or a heavy coating.

For these reasons, the observed efficiencies ranged from 12 to over 200%, but four were between 73 and 90%. The actual capture efficiencies of can coating operations are apparently lower than that observed for paper coating partially for the reasons cited above. Also, the facilities tested were not originally designed to recover fugitive VOC emissions. There are generally no hoods or floor sweeps positioned near the applicators and flash-off zones. Where solvents with a high molecular weight are used, the presence of floor sweeps can enhance the capture efficiency.

Add-On Control Device Efficiency

Because of the wide variety of solvents used in can coating formulations, the fact that several solvents may be used at one time and the fact that some are water soluble, carbon adsorbers are not generally used to recover VOC emissions. Rather, thermal or catalytic afterburners are used to destroy the emissions.

The efficiencies of the afterburners tested in this program were not typical of well designed and operated afterburners. In all three instances, the operating temperatures were significantly below that required to fully combust hydrocarbons. Thermal oxidizers should operate at 1400-1500°F with a residence time of at least 0.3 seconds to be effective. The design operating temperature for catalytic oxidizers is a function of the particular catalyst used, but is generally greater than 600°F. The catalyst in this type of unit is subject to poisoning and should be replaced when the performance deteriorates to such an extent that increasing the operating temperature is ineffective in maintaining a high VOC destruction efficiency.

The 89% efficiency of the thermal unit at site R is close to the 90 to 95% values achievable by properly functioning systems.

Overall Control Efficiency

None of the can coating facilities tested in the program have an overall control efficiency in excess of 65%. Since it is feasible to operate afterburners at 90-95% efficiency, it is the design and operation of the VOC capture system that is the more critical step in achieving a 75 or 81% overall control efficiency. The emission sources are generally categorized as being either from the coater/flash-off areas or from the curing ovens. The proposed NSPS for the beverage can surface coating industry[13] indicates in §60.493 the distribution of emissions between coater/flashoff and curing oven areas shown in Table 6-2. The values are based on information presented in the can coating CTG[14]. It further states on page 78989 of Reference 13 that industry representatives agreed that the values are representative of the industry.

The ease of controlling these emissions is site-specific, and although the oven emissions are simpler to control since they are already contained in a vessel, there are several design and operating parameters to keep in mind to ensure that the capture of the emissions from any source are maximized. Modifications that might enhance the capture of VOC emissions in curing ovens are:

- Seal the coating room so that it is always under a slight negative pressure. This assures that all fugitive VOC emissions are either captured by hoods or floor sweeps or drawn into the baking oven.
- Maintain the oven under the lowest absolute pressure so that the vaporized VOC's do not escape into the coating room or into any subsequent cooling zone with a separate exhaust into the atmosphere.
- Minimize inlet and outlet openings, inspection ports, etc., on the oven to reduce air flow requirements, yet remain below the recommended 25-40% LEL limits set for safety reasons.

TABLE 6-2. DISTRIBUTION OF VOC EMISSIONS*

Coating Operation	Emission Distribution	
	Coater/ flashoff	Curing Oven
2-piece aluminum or steel cans:		
Exterior base coat operation	0.75	0.25
Overvarnish coating operation	.75	.25
Inside spray coating operation	.80	.20
3-piece steel cans:		
Exterior base coat operation	.10	.90
Interior base coat operation	.10	.90
Overvarnish coating operation	.10	.90
Inside spray coating operation	.80	.20
Steel ends:		
Exterior coating operation	.10	.90
Interior coating operation	.10	.90

*Reference 13

The collection of VOC from the coating/flash-off areas requires more ingenuity because the operations frequently are of necessity spread out. Until recent years, efforts to consolidate these operations and capture emissions were minimal.

Where it is not feasible to seal the entire coating room, collection of emissions from the coater flash-off area may be enhanced by using hoods mounted above the coater and/or conveying line, slot hoods closely mounted adjacent to, and at the same elevation as, the coating line, or "floor sweeps" which are collection devices mounted at floor level to capture heavy VOC vapors. Also, the installation of baffles will minimize cross drafts in the flash-off area.

The exhaust from the drying or curing zone of the oven is the richest in VOC, as demonstrated at Plants L and M, and is most suitable for control in an afterburner. The exhaust from the cooling zones may also contain VOC vapors, but are in lower concentration and frequently large in volume relative to the drying zone exhaust.

Fugitive Emissions

Instantaneous measurements of hydrocarbon concentration taken at the two plants reflected a pattern similar to that noted at paper coaters and shown in Figure 6-1. It indicates that some of the solvent vapors flashed-off ahead of the oven may be drawn into the oven if there is an adequate draft. Although there is no solvent adsorbed in the metal sheets, the surface coating may account for the release of a slight amount of residual solvent vapors. It is the application and flash-off zones that deserve the greatest attention in the design of hoods for capture of vapors and location of baffles to minimize entrainment of fugitives by air currents.

6.3 ANALYTICAL PROCEDURES FOR EVALUATING EMISSION CONTROL SYSTEMS

Ideally, emissions of volatile organic compounds would be expressed as the sum of the masses of the individual components. However, in practice, many emission sources contain a variety of chemical species and it is difficult to identify and quantify them without expending considerable time and effort on the laboratory analyses of gas or liquid samples. Simple techniques using a GC with an FID can be used to estimate the concentration of several components, collectively. The concentration can be expressed as equivalent methane, ethane, or propane. This procedure is subject to inaccuracies because of the wide variation in detector response factors for individual components.

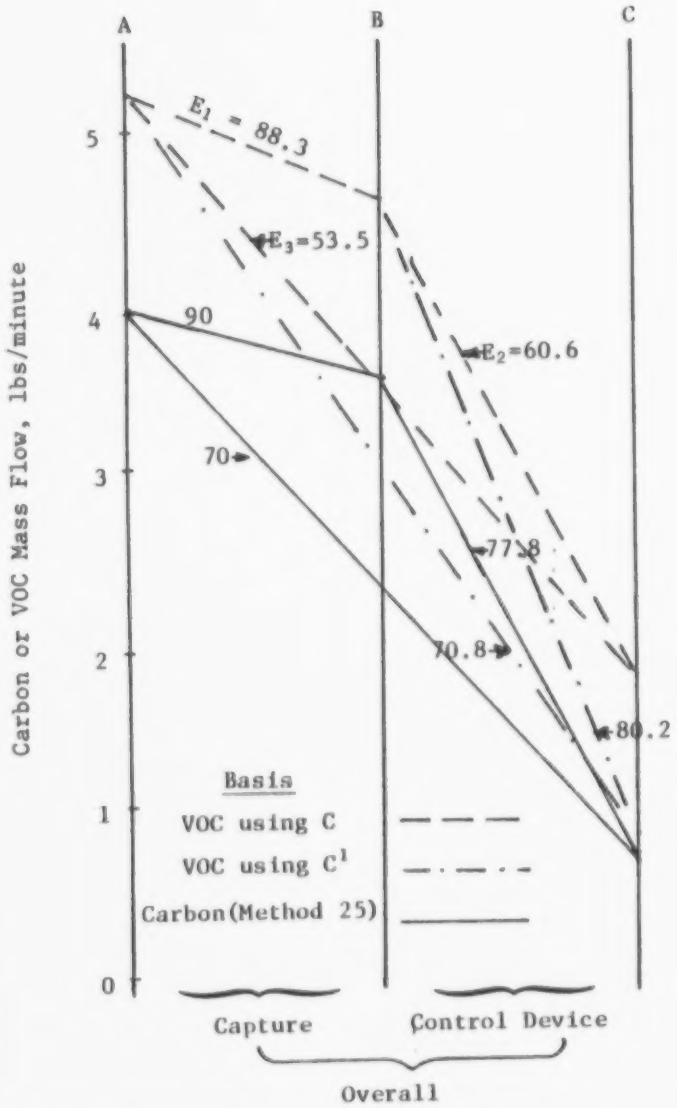
Therefore, a more direct approach that is being more widely accepted is to express the emissions as the mass of carbon emitted. It uses the recently developed EPA Method 25 for "Total Gaseous Nonmethane Organics" (TGNMO). This procedure was first used in California in the early 1970's and has been well accepted. The field sampling procedure is relatively simple and can be easily learned. The analytical procedures are relatively fast and the results are reproducible, but they require a moderately complex and expensive gas chromatographic apparatus with oxidation and reduction capabilities. As Method 25 gains more acceptance nationwide, the number of laboratories providing this service will probably increase and the costs may decrease. There have been several studies initiated to further evaluate Method 25.

EPA Method 25 is suitable for analyzing gas samples such as the vapor collected in a hood leading to a control device and the exhaust from that device. This permits a ready and accurate calculation of control equipment efficiency. Unfortunately, as yet, there is no accepted chemical method for analyzing a liquid coating mixture to determine the carbon content of the volatile fraction. The value can be calculated from a knowledge of the coating formulation; i.e., its volatile content by weight, and the

weight or volumes of individual solvents used in the mixture. However, this detailed information is not always available especially if a "nominal" solvent blend is recycled to the mix vessel and components are added "on the run" to bring the physical performance of the coating into the desired ranges. It therefore appears necessary to develop an acceptable laboratory procedure for determining the carbon content of coating liquids so that the calculation of collection efficiency and overall efficiency may be performed on a consistent basis, i.e., a carbon mass balance.

In this test program, one manufacturer, Plant C, provided a calculated value for the carbon content, but for the other sites, an attempt was made to obtain the carbon content of the coating mixture by using an oxidation-reduction technique (as in Method 25) on the solvent fraction distilled from the mixture. Although the recovery of solvent in the distillation ranged from 38 to 98%, the carbon content by analysis agreed closely with that obtained from calculation of the nominal formulation provided by the plants as indicated in Table 4-1.

Using the mass of VOC as the basis for calculating performance has been the recommended procedure in many regulations, but if a change in composition occurs between points of analysis, the calculated values are less meaningful. This can be demonstrated by reference to Figure 6-2 where the capture efficiency, E_1, control device efficiency, E_2, and overall efficiency, E_3, are calculated using two different bases, either VOC mass, or carbon mass. If the solvent in the coating mixture at Point A is initially a 50/50 blend of xylene and butyl cellosolve, the carbon concentration is 75.8%; i.e., 5.28 pounds of solvent mix contains 4.0 pounds of carbon. However, if at the oven outlet, B, the ratio of solvent components is found to be 55/45 reflecting a selective fugitive loss of cellosolve ahead of the oven, the carbon concentration is 77.3%. If it is further determined that when these vapors are oxidized in an afterburner, the remaining exhaust vapors at Point C contain a significant amount of



EQUATIONS FOR CALCULATING EFFICIENCY

$$\text{Capture} = E_1 = \frac{B}{A} \times 100$$

$$\text{Control Device} = E_2 = \frac{B-C}{B} \times 100$$

$$\text{Overall} = E_3 = E_1 \times E_2 \times 0.01$$

$$= \frac{B}{A} \times \frac{B-C}{B} \times 100 = \frac{B-C}{A} \times 100$$

where A = Applicator Rate
B = Carbon Rate to Control Device
C = Carbon Rate from Control Device

Note: Calculations for adjacent diagram are based on the following assumed compositions:

Formula	Xylene C_8H_{10}	Butyl Cellosolve $C_6H_{14}O_2$	Formaldehyde CH_2O	Solvent Mix Calc'd
Wt% C	90.6	61	40	Wt% C
Stream				
A	50	50	--	75.8
B	55	45	--	77.3
C	5	5	90	43.6
C'	90	5	5	86.6

Figure 6-2. Graphical comparison of bases for calculating emission control efficiencies.

formaldehyde, the carbon concentration would be only 43.6%. From these analyses and a change in VOC mass from 5.28 to 4.66 to 1.83, at A, B, and C, efficiencies E_1, E_2, and E_3 based on VOC's are calculated to be 88.3, 60.6, and 53.5%, respectively. However, the same efficiencies based on the carbon mass (determined by Method 25) would be 90, 77.8, and 70%.

As a further example, if the composition of the remaining VOC's at Point C were 90% xylene, as shown in the table as C^1, a significantly different set of E_2 and E_3 efficiencies would be reported based on VOC's, even though the carbon based values would be unchanged.

These examples show that the calculated control efficiency values are dependent on an accurate identification and quantification of the individual VOC components. Also, since the composition of the mixture of VOC vapors is most likely to change between the applicator and the afterburner outlet, the result is an efficiency value which has a mixed or vague basis of calculation.

It is therefore recommended that consideration be given to using carbon concentration, rather than VOC concentration, as the basis for calculating the capture, control device and overall efficiencies.

REFERENCES

1. Rolke, R. W., et al. Afterburner Systems Study. Shell Development Co., Emeryville, California. EPA Contract No. ESHD 71-3. EPA-R2-72-062, August 1972.

2. Industrial Surface Coating (Can Coating), Emission Test Report. Metal Container Corporation, Jacksonville, Florida. U.S. EPA, EMB Report 79-1SC-8, December 1979.

3. Industrial Surface Coating Cans, Emission Test Report. American Can, Forest Park, Georgia. U. S. EPA, EMB Report 79-1SC-7, August 1979.

4. Pantalone, J. S. and L. Shepard. Consideration of Model Rule for the Control of Volatile Organic Compound Emissions from Can and Coil Coating Operations. California Air Resources Board, July 26, 1978.

5. Nelson, T. P. Trip Report on Paper Coating Facilities, Manufacturer A. Radian Corporation, Austin, Texas (Docket confidential file).

6. Pressure Sensitive Tape and Label Surface Coating Industry, Background Information for Proposed Standards, Draft EIS, App. C, pp 3-8.

7. Reference 6, App. C, pp 3-7.

8. Reference 6, App. C, pp 8-13.

9. Reference 6, App. C, pp 3-4.

10. Reference 6, App. C, pp 3-4.

11. Federal Register, Vol. 45, No. 36, February 21, 1980, Rules and Regulations, p 11482.

12. Package Sorption Systems Study. MSA Corporation, Evans City, Pennsylvania. EPA R2-73-202, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, Contract EHSD 71-2, April 1973.

13. Federal Register, Vol. 45, No. 230, November 26, 1980. Proposed Rules, Standards of Performance for New Stationary Sources; Beverage Can Surface Coating Industry.

14. Control of Volatile Organic Emissions from Existing Stationary Sources, Volume II: Surface Coating of Cans, Coils, Paper, Fabrics, Automobiles and Light Duty Trucks. EPA-450/2-77-008, May 1977.

15. Reference 6, p 3-14.

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APPENDIX A

TEST METHODS

STANDARD METHOD OF TEST FROM ASTM STANDARDS, PART 25

Philadelphia, Pennsylvania

1 Standard Method of Test for Density of Paint, Varnish Lacquer, and Related Products
D-1475-60, pp. 273-275

2 Volatile Content of Solvent-Reducible Paints
D-2369-80, pp. D-4-5

3 Vacuum Distillation of Solvents from Solvent-Base Paints for Analysis
D-3272-76, pp. 611-613

U.S. EPA METHODS IN 40 CFR PART 60,
APPENDIX A, PP. 88-128

4 Method 1 - Sample and Velocity Traverses for Stationary Sources

5 Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

6 Method 3 - Gas Analysis for Carbon Dioxide, Oxygen, Excess Air, and Dry Molecular Weight

7 Method 4 - Determination of Moisture Content in Stack Gases

8 Method 25: Determination of Total Gaseous Non-Methane Organic Emissions as Carbon
Federal Register, Vol. 45, No. 194, October 3, 1980, pp. 65959-73.

APPENDIX B

TEST INSTRUMENT CALIBRATION DATA AND DESCRIPTIVE INFORMATION

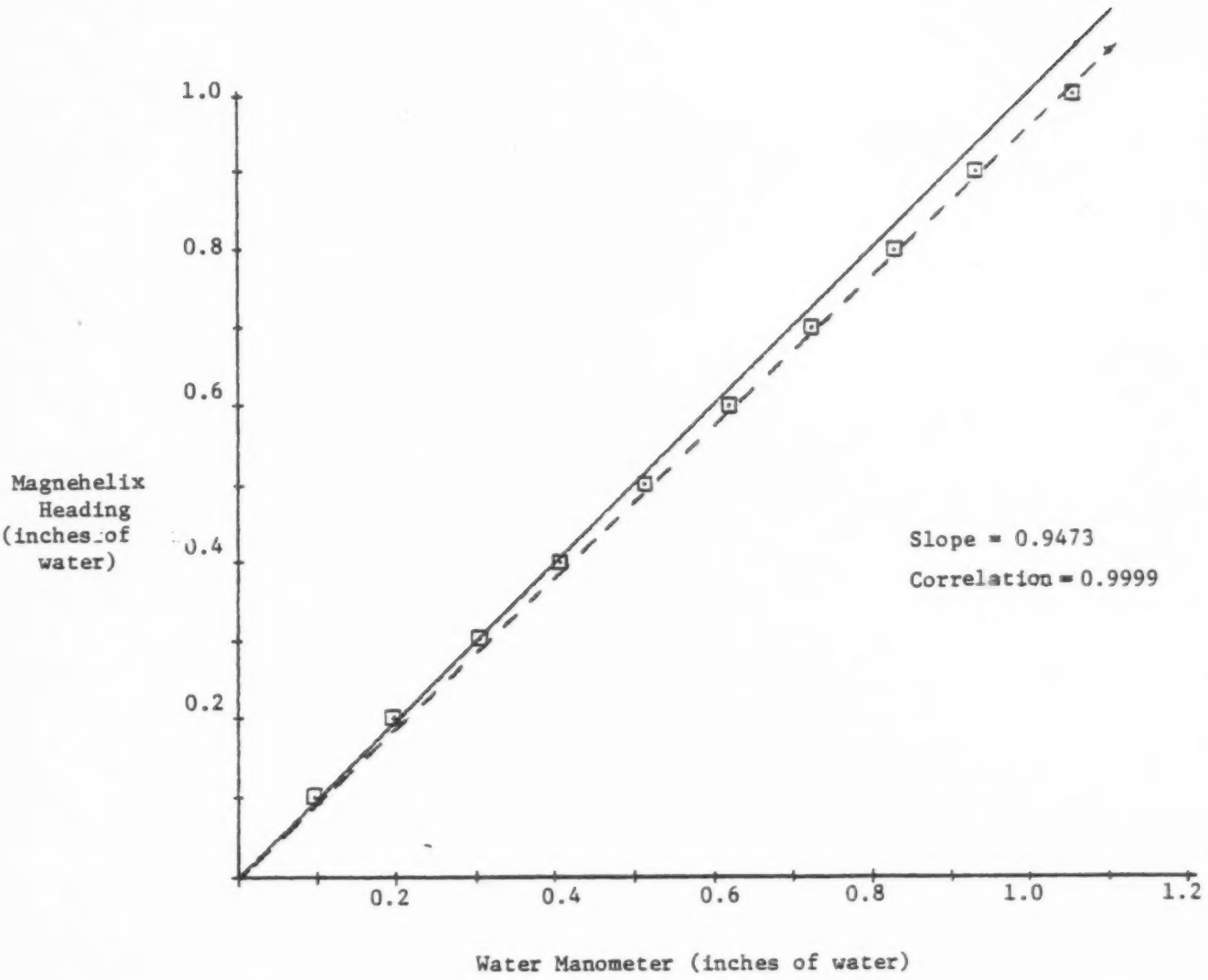


Figure A-1. Calibration curve for one-inch H_2O Magnehelix (#70923 mm69)

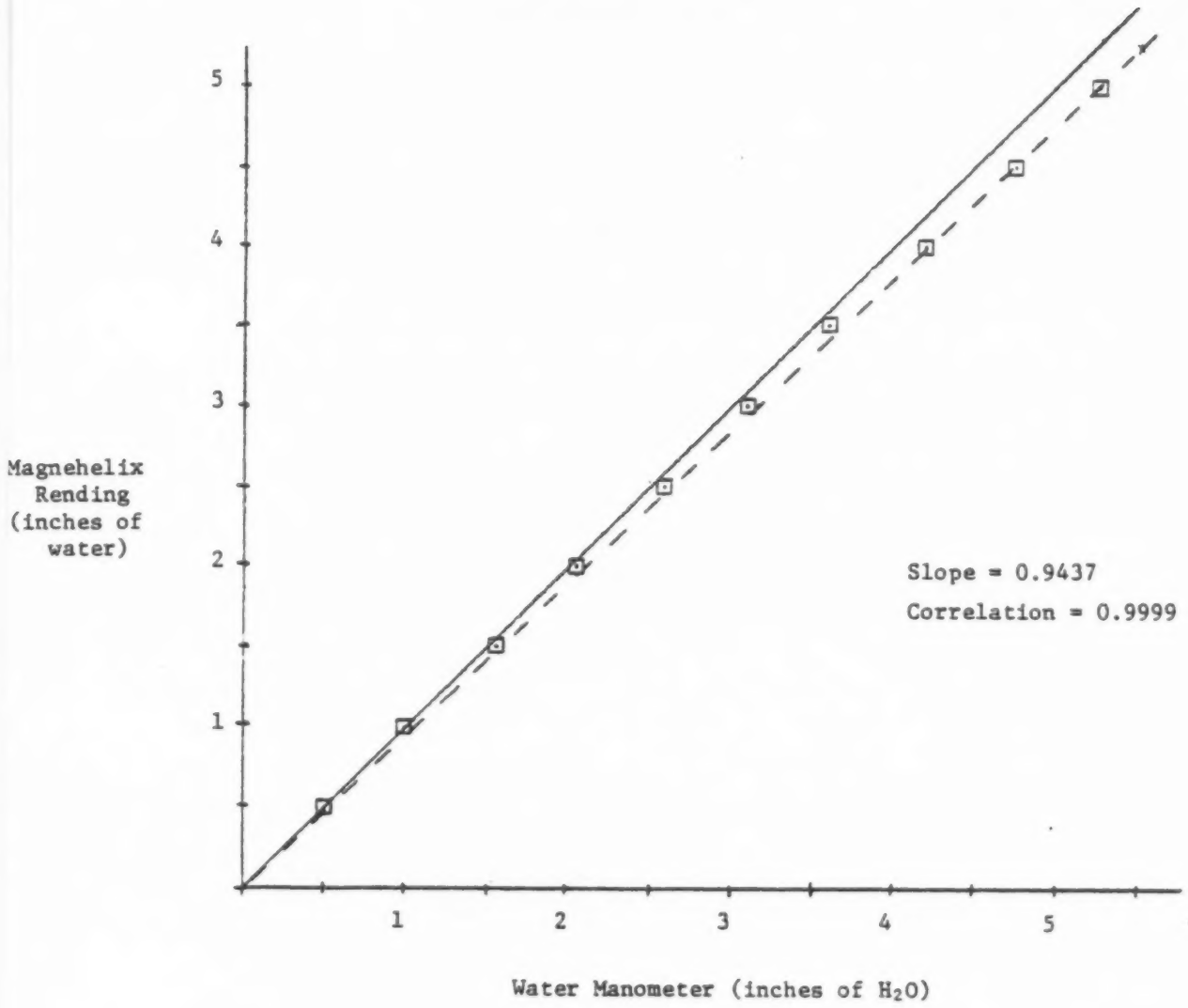


Figure A-2. Calibration curve for five-inch H_2O Magnehelix (#805195524)

LACE ENGINEERING
A SUBSIDIARY OF NAPP, INC.
8825 NORTH LAMAR BLVD.
AUSTIN, TEXAS 78753

6 FOOT BARE "S" TYPE PITOT

PITOT TUBE IDENTIFICATION NUMBER: 418 DATE: 11/2/80

CALIBRATED BY: [illegible] CALIBRATED WITH [illegible]

"A" SIDE CALIBRATION

RUN NO.	ΔP_{std} cm H_2O (in. H_2O)	$\Delta P_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1	.31	.44	.831	-.007
2	.235	.33	.835	-.002
3	.15	.205	.847	.009
		$\bar{C}_p$ (SIDE A)	.838	$\sigma = .006$

"B" SIDE CALIBRATION

RUN NO.	ΔP_{std} cm H_2O (in. H_2O)	$\Delta P_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1	.31	.44	.831	-.011
2	.235	.32	.848	.006
3	.15	.205	.847	.005
		$\bar{C}_p$ (SIDE B)	.842	$\sigma = .007$

AVERAGE DEVIATION = σ(A OR B) = $\frac{\sum_{1}^{3} \left| C_p(i) - \bar{C}_p(\text{A OR B}) \right|}{3}$ ← MUST BE < 0.05

$\left| \bar{C}_p(\text{SIDE A}) - \bar{C}_p(\text{SIDE B}) \right|$ ← MUST BE < 0.01 $\quad C_{p(s)} = 0.99 \sqrt{\frac{\Delta P_{std}}{\Delta P_s}}$

$\bar{C}_p$ green $- \bar{C}_p$ Red

$|.838 - .842| = .004$

OPERATING INSTRUCTIONS

FOR ALNOR SERIES 6000-P VELOMETER®

SERIES 6000-P

ALNOR®
INSTRUMENT COMPANY

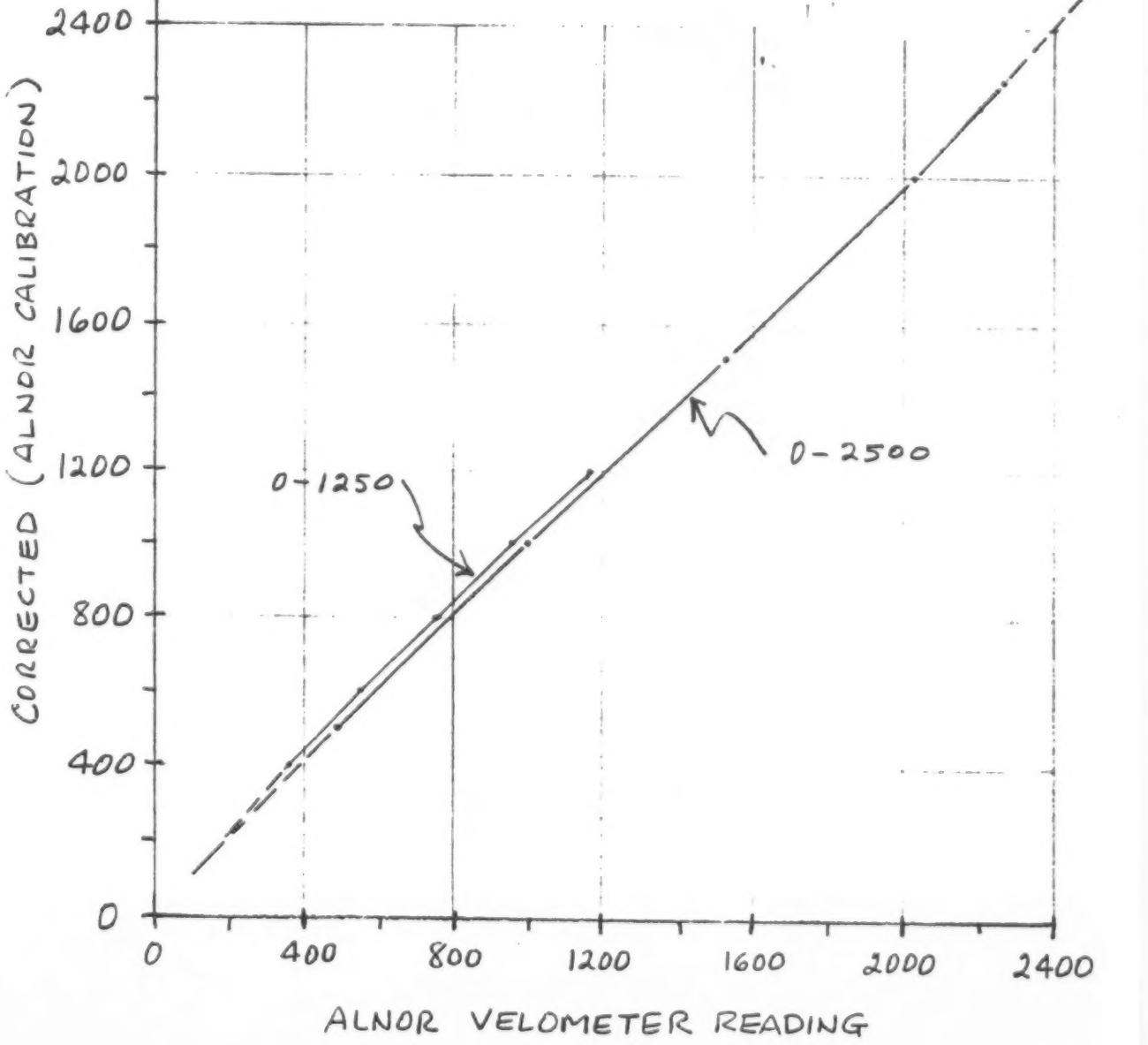
ALNOR INSTRUMENT COMPANY
CHICAGO, ILLINOIS 60610
INSTRUMENTS FOR MEASUREMENT AND CONTROL
TEMPERATURE • PRESSURE • FLOW • HUMIDITY

FORM 6270

ALNOR Model No. 6000 AP
CALIBRATION 9-18-80

24" Probe

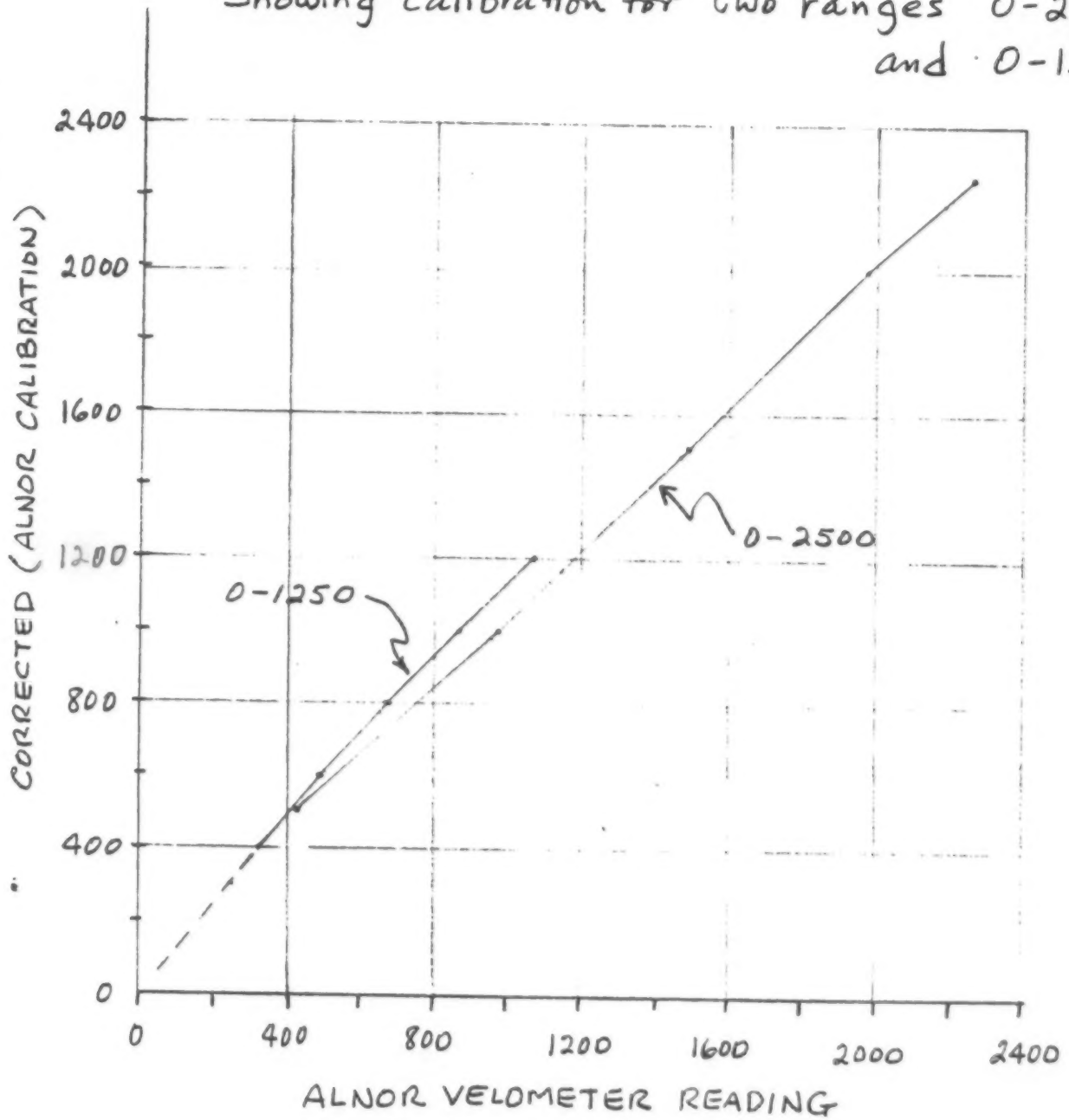
Showing Calibration for two ranges 0-25
and 0-12



ALNOR Model No. 6000 AP
CALIBRATION 9-18-80

36" Probe

Showing Calibration for two ranges 0-2500 and 0-1250



CARL POE CO., INC. 99 REINERMAN ST. • HOUSTON, TEXAS 77007 • 713-861-3816

August 26, 1980

Radian Corporation
P.O. Box 9984
Austin, TX 78766

Ref: #35711
Sub: Certification of Calibration

Dear Sir:

This is to certify that the following Rockwell Dry Gas Meters have been calibrated with American Bell Prover #1763, which is traceable to Bureau of Standards, reference #26727, PI-TAPE.

#704584	15 cft.	0.0% ±
	30 cft.	0.0% ±
	45 cft.	0.2% +
#715573	15	0.0% ±
	30	0.0% ±
	45	0.0% ±
#696761	15	.9% +
	30	.9% +
	45	.9% +
#706941	15	.2% -
	30	0.0% ±
	45	0.0% ±

Sincerely,

CARL POE CO., INC.

Carl W. Poe

CWP:mv

APPENDIX C

TYPES OF COATINGS AND SOLVENTS USED

APPENDIX C. TYPES OF COATINGS AND SOLVENTS USED

Can Coating	Coating	Solvents
L	Oleo resins (75 wt %) Phenolic Water-based Vinyl	S-Thinner Cellosolve acetate Butyl cellosolve Xylene Isophorone H-thinner
M	Epoxics Phenolics Alkyds Vinyls Pigmented inks	X-A (67% xylene, 33% diacetone alcohol) Lacquer thinner (50% MIBC, 45% xylene) 5% isophorone Vinyl solvents (75% xylene, 25% MIBK) E-Solvent (50% xylene, 50% butyl cellosolve)
Paper Coating		
C	Adhesive	Confidential
D	Pressure-sensitive adhesive	Toluene and others
E	Nitrocellulose	Toluene, ethyl acetate, isopropanol

MIBC = methylisobutyl carbinol
MIBK = methylisobutyl ketone

APPENDIX D

ANALYTICAL RESULTS

pcs/lab
Pollution Control Science, Inc.
6015 Manning Road, Miamisburg, Ohio 45342
(513) 866-5908 TLX 288-348

Report Date: 12-3-80
Date Rec'd: 10-27-80
PCS Sample#: 03780 thru 03815
Client P.O.#: 37064
Inv#/Acct#/PN: 150-1

RADIAN CORPORATION

ACCREDITED BY THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION
CERTIFIED BY THE OHIO EPA FOR DRINKING WATER ANALYSES
MEMBER OF THE AMERICAN COUNCIL OF INDEPENDENT LABORATORIES

PLANT M — PLATE OVENS 1 AND 2

TOTAL GASEOUS NONMETHANE ORGANICS (TGNMO)

PCS Sample Number		EMISSION SOURCE ID	SAMPLE VOLUME	TRAP ppm C1	TANK ppm C1	TOTAL ppm C1	TOTAL mg/L C1	TRAP No.	TANK No.
03801		2 -0I-1	2.762	2 739	10.8	2 750	1.373	12	37
03803	*	2 -0I-2A	3.148	1 790	530	2 320	1.158	27	75
03802	*	2 -0I-2B	2.730	3 129	17.2	3 146	1.571	50	82
03798		2 -0I-3	3.513	1 856	9.5	1 866	0.392	47	83
03799		2 -0I-4	2.503	3 192	207	3 399	1.697	40	77
03804		2 -00-1	3.089	1 314	27.3	1 341	0.670	16	45
03805		2 -00-3	3.586	1 345	18.4	1 363	0.681	52	84
03800		2 -00-4	2.184	1 821	27.3	1 848	0.923	62	13
03796		2 -CZ-1	4.045	109	< 5	109	0.054	82	38
03797		2 -CZ-3	3.323	95.3	82.3	178	0.089	212	39
03813		1 -0I-1	3.431	2 342	170	2 512	1.254	208	87
03808	*	1 -0I-2A	3.333	2 754	29.1	2 783	1.390	55	85
03809	*	1 -0I-2B	3.169	2 470	218	2 688	1.342	29	86
03815		1 -0I-3	2.829	1 011	58.7	1 070	0.534	202	78
03814		1 -0I-4	2.803	3 823	204	4 027	2.011	213	79
03811		1 -00-1	3.267	2 238	48.2	2 286	1.142	88	40
03810		1 -00-3	3.778	86.1	53.8	139.9	0.070	39	41
03812		1 -00-4	3.281	2 846	250	3 096	1.546	-	88
03807		1 -CZ-1	4.746	69.5	< 5	69.5	0.035	49	42
03806		1 -CZ-3	3.568	167	13.0	180	0.090	87	43

* Duplicate Samples

PROCEDURES IN ACCORDANCE WITH 40 CRF Part 136 October 16, 1973 (38 FR 28758), and amendments.

David Robinson

The information contained herein is the confidential property of our clients. Disclosure of such data, statement or conclusion requires written approval.

pcs/lab

12-3-80
RADIAN CORPORATION

PLANT M

1	-	0I	-	1
OVEN DESIGNATION		SAMPLING LOCATION		SAMPLING PERIOD

SAMPLING LOCATIONS:

0I - Oxidizer Inlet

0O - Oxidizer Outlet

CZ - Cooling Zone

pcs/lab
Pollution Control Science, Inc.
6015 Manning Road, Miamisburg, Ohio 45342
(513) 866-5908 TLX 288-348

Report Date: 12-3-80
Date Rec'd: 10-27-80
PCS Sample#: 03780 thru 0381
Client P.O.#: 37064
Inv#/Acct#/PN: 150-1

RADIAN CORPORATION

ACCREDITED BY THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION
CERTIFIED BY THE OHIO EPA FOR DRINKING WATER ANALYSES
MEMBER OF THE AMERICAN COUNCIL OF INDEPENDENT LABORATORIES

PLANT L

PLATE OVEN No. 2

TOTAL GASEOUS NONMETHANE ORGANICS (TGNMO)

PCS Sample Number		EMISSION SOURCE ID	SAMPLE VOLUME	TRAP ppm C1	TANK ppm C1	TOTAL ppm C1	TOTAL mg/L C1	TRAP No.	TANK No.
03794		2-0I-1	3.458	1 676	110	1 786	0.892	7	60
03791	*	2-0I-2A	3.016	1 627	69.4	1 696	0.874	46	53
03790	*	2-0I-2B	1.819	1 391	136	1 527	0.763	85	52
03780		2-0I-3	2.930	554	101	655	0.327	35	68
03781		2-0I-4	2.219	1 494	79	1 573	0.786	53	69
03795		2-00-1	2.745	208	74	282	0.141	102	70
03787	*	2-00-3A	3.202	571	42.1	613	0.306	101	44
03786	*	2-00-3B	3.607	406	47.9	454	0.227	51	71
03785		2-00-4	3.176	127	81.2	208	0.104	31	64
03792		2-CZ/A-1	2.629	82.1	139	221	0.110	24	48
03788	*	2-CZ/A-3A	2.524	155	104	259	0.130	13	49
03789	*	2-CZ/A-3B	3.093	123	57.7	180	0.090	95	74
03793		2-CZ/B-1	3.150	108	117	225	0.112	57	72
03782	*	2-CZ/B-3A	3.064	435	84	519	0.259	84	56
03783	*	2-CZ/B-3B	2.938	161	102	263	0.131	61	73
03784		-FS-1	2.894	210	28.6	239	0.119	89	51

* Duplicate Samples

PROCEDURES IN ACCORDANCE WITH 40 CRF Part 136 October 16, 1973 (38 FR 28758), and amendments.

David Robinson

The information contained herein is the confidential property of our clients. Disclosure of such data, statement or conclusion requires written approval.

2	-	0I	-	1
OVEN DESIGNATION		SAMPLING LOCATION		SAMPLING PERIOD

SAMPLING LOCATIONS:

0I - Oxidizer Inlet

0O - Oxidizer Outlet

CZ/A - Cooling Zone A

CZ/B - Cooling Zone B

FS - Floor Sweep

REPORT

TRUESDAIL LABORATORIES, INC.

CHEMISTS - MICROBIOLOGISTS - ENGINEERS
RESEARCH - DEVELOPMENT - TESTING

4101 N. FIGUEROA STREE
LOS ANGELES 9006
AREA CODE 213 • 225-156
CABLE: TRUELAB

CLIENT Radian Corporation
Post Office Box 9948
Austin, Texas 78766
ATTN: Mr. Bill Stadig

DATE January 13, 1981

RECEIVED October 14, 1980

LABORATORY NO. 34533

SAMPLE 20 - hydrocarbon samples collected by USEPA Method 25 and 10 - paint distillate samples.
P. O. No. 37066

INVESTIGATION

Analysis of hydrocarbon samples by USEPA Method 25 and carbon determination on paint distillate samples.

RESULTS

Evacuated 8 liter tanks and stainless steel freezeout traps were sent by air freight to Tom Nelson in La Grange, Illinois. The returned samples were analyzed by a Total Combustion Analysis Method (equivalent to USEPA Method 25 in South Coast Air Quality Management District).

Total of 12 samples were taken into 8 liter tanks and 8 samples were taken with 6.8 liter aluminum tanks.

The submitted paint distillate samples were also analyzed for carbon content.

The results are given in the following tables.

This report applies only to the sample, or samples, investigated and is not necessarily indicative of the quality or condition of apparently identical or similar products. As a mutual protection to clients, the public and these Laboratories, this report is submitted and accepted for the exclusive use of the client to whom it is addressed and upon the condition that it is not to be used, in whole or in part, in any advertising or publicity matter without prior written authorization from these Laboratories.

Summary of the Results

Sample	[Plant]	Carbon Dioxide (CO_2), ppm	Carbon Monoxide (CO), ppm	Hydrocarbons: Methane (CH_4), ppm	Hydrocarbons: Gaseous (as C_1), ppm	Hydrocarbons: Condensable (as C_1), ppm	Hydrocarbons: Total (as C_1), ppm
R-1	C1	8900	936	30	2600	11,020	13,620
R-2	C1	7000	981	27	5400	9,031	14,431
R-3	C1	8800	992	33	5600	8,488	14,088
R-4	C2	24,600	4160	22	283	314	597
R-5	C1	7400	1033	28	4800	10,490	15,290
R-6	C2	23,500	4100	21	639	512	1151
R-7	C2	25,000	3900	23	105	739	844
R-10	C1	8100	1014	39	6300	7,595	13,895
T-1	D	515	ND	ND	487	1531	2018
T-2	D	416	ND	ND	220	1809	2029
T-3	D	2483	ND	ND	ND	2203	2203
T-4	D	1006	ND	ND	ND	1214	1214
T-5	D	NR	ND	ND	ND	919	919
T-6	D	NR	ND	ND	ND	1767	1767
T-7	E	423	< 15	< 15	ND	153	153
T-8	E	2319	< 10	< 10	ND	120	120
T-9	E	3976	< 10	< 10	ND	58	58
T-10	E	3140	< 10	< 10	ND	90	90
T-11	E	2798	< 10	< 10	ND	42	42
T-12	E	2320	< 10	< 10	ND	159	159

C1 = Incinerator Inlet, Plant C
C2 = Incinerator Outlet, Plant C
D = Absorber Outlet, Plant D
E = Absorber Outlet, Plant E
ND = None detected
NR = Not reported

Carbon content of solvents (paint distillates)

Sample No.	Plant	% (by weight) Carbon (C)	
Received on 11/18/80			
33	D	75.51	
14	D	86.85	
18	E	74.82	
Received on 12/1/80			
1	M	74.28	
7	L	84.83	
9	L	85.50	
11	D	89.86	(sample appeared
12	D	88.73	cloudy)
15	D	87.03	
16	D	88.58	(non-homogeneous material in the sample)

Gas Tanks

Tank No.	Volume Liters	"Hg Res. Vac.	Temp °F	Barometric Pressure "Hg (corr.)
T-1	7.75	-6.0	80	29.53
T-2	8.20	-7.7	-"-	-"-
T-3	7.67	-20.1	-"-	-"-
T-4	8.23	-5.6	-"-	-"-
T-5	8.24	-6.4	-"-	-"-
T-6	8.21	-14.6	-"-	-"-
T-7	8.083	-14.0	72	29.40
T-8	8.138	-10.0	-"-	-"-
T-9	8.052	-11.8	-"-	-"-
T-10	7.905	-9.4	-"-	-"-
T-11	8.12	-10.4	-"-	-"-
T-12	8.11	-12.2	-"-	-"-
	Aluminum Tanks*			
R-1	6.80	-11.4	72	29.40
R-2	6.80	-7.6	74	29.60
R-3	6.80	-7.2	74	29.60
R-4	6.80	-8.6	72	29.40
R-5	6.80	-5.8	72	29.60
R-6	6.80	-8.6	74	29.60
R-7	6.80	-15.2	74	29.60
R-10	6.80	-6.6	74	29.60

*Two aluminum tanks were standardized for volume. Both came out to be 6.80 ± 0.003 liters. Therefore 6.80 L. volume was used for the rest of the aluminum tanks.

The traps were matched with gas tanks as marked.

Respectfully submitted,

TRUESDAIL LABORATORIES, INC.

Ignas Bandziulis

Ignas Bandziulis
Supervisor, Air Pollution Testing

APPENDIX E

MATERIAL BALANCE CALCULATIONS FOR PLANT L

MATERIAL BALANCE CALCULATIONS FOR PLANT L

Solvent Use at the Applicator (as C_1)

$$\frac{\text{lb VOC as } C_1}{\text{min}} = 105 \frac{\text{sheets}}{\text{min}} \times \frac{33\ 125'' \times 33.369''}{\text{sheet}} \times \frac{5\ \text{mg/in}^2}{1000\ \text{mg/g} \times 454\ \text{gm/lb}} \times 0.2269 \frac{\text{lb solvent}}{\text{lb coating}} \times 0.8483 \frac{\text{lb } C_1}{\text{lb solvent}}$$

$$= 0.246 \text{ lb } C_1/\text{min}$$

Afterburner Outlet

ppm as C_1	gas flowrate
282	
613	
454	8,120
208	7,830
ave 389	7,975 scfm

$$\frac{\text{lb C}}{\text{min}} = \frac{389}{10^6} \times 12.01 \text{ lb/lb mole} \times \frac{7975 \text{ scfm}}{387 \text{ scf/lb mole}} \times 0.958$$

$$= 0.0922$$

Afterburner Inlet

ppm as C_1
1786
1696
1527
655
1573
1447

The incinerator inlet flowrate is assumed equal to outlet flowrate (on a dry basis). There is no excess air added to the incinerator.

$$\frac{\text{lb } C_1}{\text{min}} = \frac{1447}{10^6} \times 12.01 \frac{\text{lb}}{\text{lb mole}} \times \frac{7975 \text{ scfm}}{387 \text{ scf/lb mole}} \times 0.958 \frac{\text{dry}}{\text{wet}}$$

$$= 0.343 \text{ lb } C_1/\text{min}$$

Cooling Zone A

ppm as C_1, dry	flowrate
221	13,340
259	13,310
180	
ave 220	ave 13,330

$$\frac{\text{lb } C_1}{\text{min}} = \frac{220}{10^6} \times 12.01 \frac{\text{lb}}{\text{lb mole}} \times \frac{13{,}330 \text{ scfm}}{387 \text{ scf/lb mole}} \times 0.986 \frac{\text{dry scf}}{\text{wet scf}}$$

$$= 0.0897 \text{ lb } C_1/\text{min}$$

Cooling Zone B

ppm as C_1, dry	flowrate
225	10,810
519	10,780
263	
ave 336	ave 10,800

$$\frac{\text{lb } C_1}{\text{min}} = \frac{336}{10^6} \times 12.01 \frac{\text{lb}}{\text{lb mole}} \times \frac{10{,}800 \text{ scfm}}{387 \text{ scf/lb mole}} \times 0.986 \frac{\text{dry scf}}{\text{wet}}$$

$$= 0.111 \text{ lb } C_1/\text{min}$$

Summary of Material Balance

lb C /min						
Applied Coating	Incinerator Inlet	Incinerator Outlet	Cooling Zone A	Cooling Zone B	% Capture	% Destrn
0.246	0.343	0.0922	0.0897	0.111	221	73